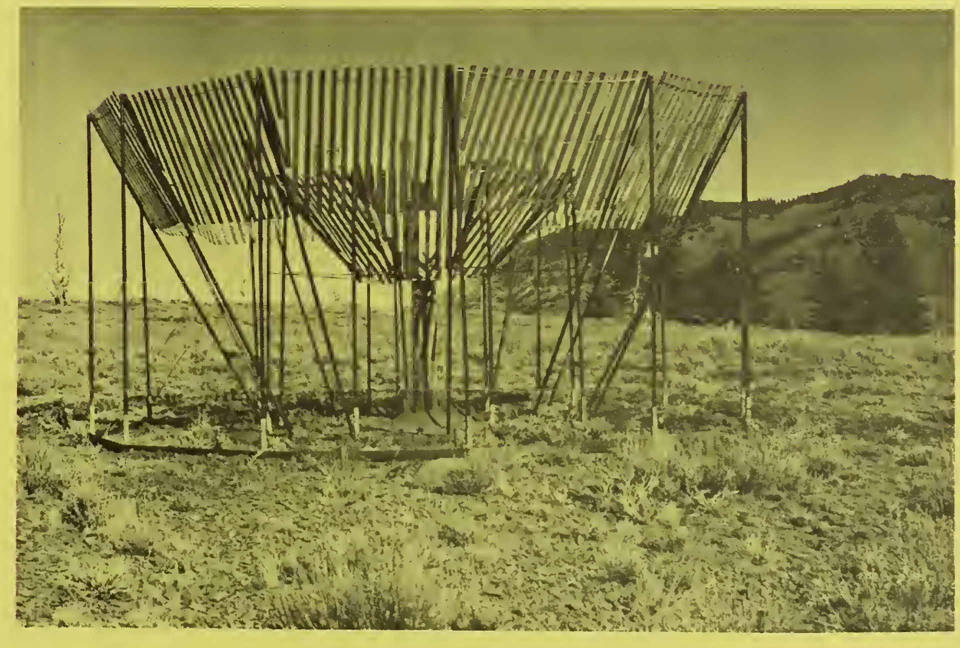
SEA-AR/BLM COOPERATIVE STUDIES

REYNOLDS CREEK WATERSHED

Northwest Watershed Research Center
Western Region
Agricultural Research
Science and Education Administration
U. S. Department of Agriculture



INTERIM REPORT NO. 9

Cooperative Agreement No. 12-14-5001-6028

For Period January 1, 1978, to December 31, 1978

TO

Denver Service Center
Bureau of Land Management
U S. Department of the Interior
Denver, Colorado

APRIL 1979

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FRONT COVER: Shown on the cover is the Wyoming shielded gage at precipitation site 127X07 on the Reynolds Creek Watershed. As discussed in the PRECIPITATION SECTION, it has optimum operating characteristics for measuring snow under very windy conditions.

NOTE: Generally, a variety of watershed data are compiled on a calendar year basis. However, the water year, beginning October 1 and ending September 30, has proven best for hydrologic comparisons.

INTRODUCTION

Cooperative watershed research between the Science and Education Administration-Agricultural Research, U. S. Department of Agriculture, and the Bureau of Land Management, U. S. Department of Interior, was initiated in 1968 under Cooperative Agreement No. 14-11-0001-4162(N). Also, the Memorandum of Understanding, dated July 6, 1960, which is a part of the Cooperative Agreement, specifies the overall responsibility of each agency.

This interim report summarizes progress and results on the Reynolds Creek Watershed and supporting studies on the Boise Front from October 1 through September 31, 1978. Data collection, processing, analyses, and reporting are according to the FY 1978 work plan. Progress reports are given by the individual sections of the work plan. A copy of the FY 1978 work plan precedes the progress reports.

Supporting information and data are presented in Northwest Watershed Research Center Annual Reports for 1972 and prior years and in Interim Reports No.'s 1, 2, 3, 4, 5, 6, 7, and 8 for the AR-BLM studies in the Reynolds Creek Watershed under Cooperative Agreement No. 14-11-0001-4162(N).

Weather - 1978 Water Year

Evidence of the 1976-1977 drought has disappeared, except for areas in which big sagebrush (*Artemisia tridentata*) were killed. Most measurement sites had average to slightly above average amounts of precipitation in water year 1978. Runoff amounts were average to slightly above average. Reduced water quality levels of the drought year did not carry over. Groundwater recharge events have returned levels to 1972 levels, which now insure adequate supplies for stock water pumping. Comparison of this report with Interim Report No. 8 will give more detail in specific comparisons with the drought year.

Progress Reports (Narrative)

The progress report section is formatted so as to follow the BLM-SEA work plan for FY 1978. Within each report section, progress is reported for each work plan item.

Progress Reports (Publications)

Publications and reports are listed, whether completed or underway. For those that are underway, the investigations and analyses were done during the reporting period.

Appendix Material

Summaries of principle accomplishments under the FY 1978 work plan are presented. The approved BLM-SEA work plan for FY 1979 is included.

The following two figures locate experimental sites on Reynolds Creek (Introduction, Figure 1) and the Boise Front (Introduction, Figure 2). At various places in the PROGRESS REPORT sections, these figures will be referred to.

Additional copies of this report, or information on material reported, can be obtained from:

Northwest Watershed Research Center
USDA-SEA-Agricultural Research
1175 South Orchard
Suite 116
Boise, Idaho 83705

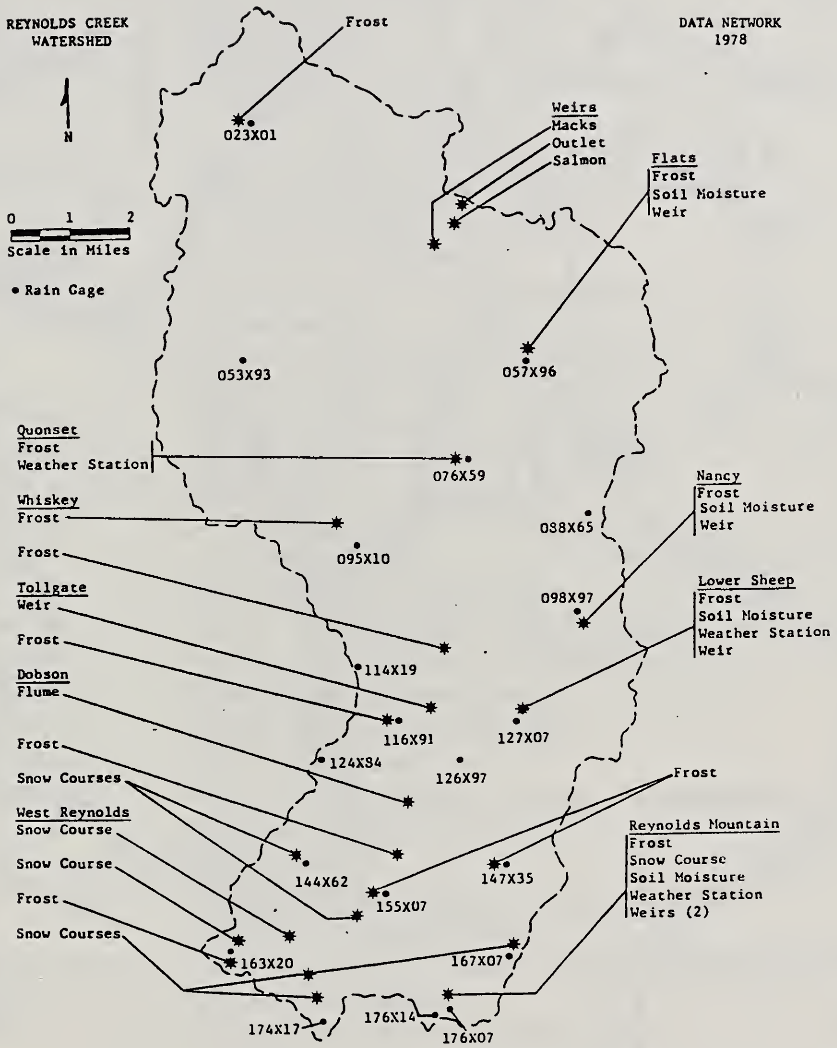

Figure 1.--Reynolds Creek Watershed

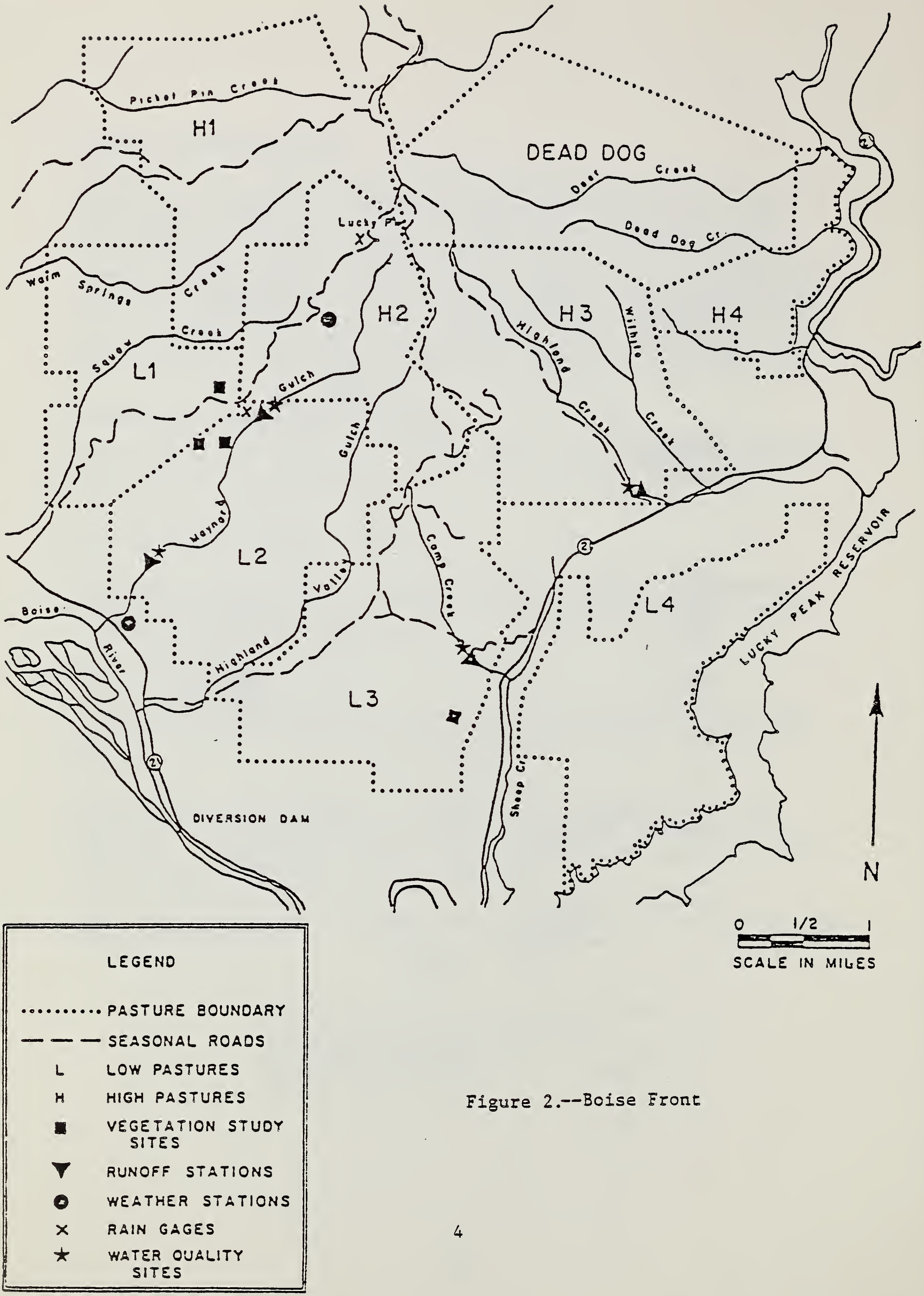

Figure 2.--Boise Front

STAFF

Name	Title	Service Dates*
Aaron, Virginia M.	Hydrologic Technician	
Belknap, Stephen P.	Maintenance Worker (180-day Appt)	2/12/78-9/8/78
Brakensiek, Donald L.	Research Hydraulic Engineer (LL and RL)	
Burgess, Michael D.	Electronic Technician	
Butler, Donna M.	Administrative Officer	
Coon, Delbert L.	Hydrologic Technician	
Cox, Lloyd M.	Hydrologist	
Engleman, Roger L.	Mathematician	
Gidley, Jess R.	Boise State Univ. Cooperator - Hydrologic Aid	1/1/78-12/2/78
Hanson, Clayton L.	Agricultural Engineer	
Harris, James H.	University of Idaho Cooperator - Research Technician	
Hoagland, Roy M.	Automotive Mechanic	
Hornbaker, Sonny	Boise State Univ. Cooperator - Technician	12/14/78-Present
Jackson, Sue	Boise State Univ. Cooperator - Technician	
Johnson, Clifton W.	Research Hydraulic Engineer	
Moreland, Bonnie	Clerk Typist (Perm.,35 Hr/wk)	1/3/77-5/20/78
Morris, Ronald P.	Hydrologic Technician	
O'Brien, Rebecca	Boise State Univ. Cooperator - Technician	5/21/78-Present
Perkins, Lee	Hydrologic Technician	
Peterson, Evelyn F.	Clerk Stenographer (35 Hr/wk)	6/5/77-6/3/78
Phillips, Nancy J.	Range Technician (180-day Appt)	4/9/78-9/21/78
Robertson, David C.	Hydrologic Technician	
Schell, Carmen J.	Clerk Typist (35 Hr/wk)	8/13/78-11/18/78
Schumaker, Gilbert A.	Soil Scientist	
Schumaker, Vera H.	Clerk Stenographer (Perm.,35 Hr/wk)	8/27/78-Present
Smith, Jeffrey P.	Hydrologic Technician	
Stephenson, Gordon R.	Geologist	
Thomson, Michael S.	University of Idaho Cooperator - Technical Aid	
Trautman, Kenneth W.	Engineering Equipment Operator	
Wilson, Glenna A.	Purchasing Agent	
Zurawski, Linda	Boise State Univ. Cooperator - Technician	5/16/77-5/5/78
Zuzel, John F.	Hydrologist	

*If other than whole year.

BLM-SEA WORK PLAN FOR FY 1978

A. Location and Title of Study. The study will be conducted within the Reynolds Creek Experimental Watershed and adjacent satellite areas within the State of Idaho; the title of the study is "Reynolds Creek Experimental Watershed Study".

B. Work Plan for FY 1978. The SEA-AR, during the FY 1978 study period, will collect and analyze data for evaluating the effects of grazing management systems on rangeland soil, water, and vegetation resources. Impacts of grazing on these resources will be determined by the following studies:

1. Precipitation

a. Utilizing a 15-year record from a 22-gage network on Reynolds Creek, a model will be developed for generating annual and monthly precipitation amounts. The influence of elevation and aspect will be incorporated into the model for defining regions for which the model can be applied.

b. A network of four dual gages in the Boise Front study area has been established to represent elevation variability. Mean annual and seasonal precipitation and elevation relationships will be compared with the AR data from Reynolds Creek.

2. Vegetation

a. On the Reynolds Creek Experimental Watershed, data collection will continue from grazed and nongrazed plots at nine sites. Observations will be made in each plot on changes in species composition and herbage yield at maximum cover. Also, soil surface factors, plot photographs, and trend plot data will be collected. Soil water data will be collected and processed biweekly during the grazing season at five study sites under both grazed and nongrazed practice. Soil water depletion models will be tested with these data. Herbage yield data through 1977 will be correlated with watershed factors, including precipitation, soil moisture, temperature, elevations, and aspect for six sites. Survival, persistence, and vigor of various species will be determined at the three nursery sites and a report will be prepared presenting recommendations of species for seeding of areas represented by the three elevation-soil sites.

b. On the Boise Front study area, data will be collected at four sites on three pastures in the rest-rotation system on changes in nonbrowse species composition, cover percentages, seedling establishment, and vigor. Comparison data will be collected from nonuse areas. Eight browse study sites will be utilized to investigate vigor and use by deer and cattle. Soil water data will be collected biweekly at four sites for characterizing soil water storage and depletion. Soil surface factors will be determined at four study sites.

3. Runoff

a. On the Reynolds Creek Experimental Watershed, runoff rates and amounts will be collected and analyzed for two microwatersheds, three source watersheds, three tributary watersheds, and two main stem watersheds. Watershed models will be developed and tested for predicting water yield and runoff rates. Investigate the correlation between mean annual and monthly runoff and precipitation for two subwatersheds. Soil frost data will be collected for runoff modeling during rain and snowmelt events.

b. On the Boise Front study area, two streamflow gaging sites have been established, with two additional sites to be completed this year. High and low elevation, rest and rotation pastures are represented in these gaged watersheds. At two of the precipitation sites, weather stations have been established for collection of temperature, relative humidity, evaporation, and wind data. At all rain gage sites, frost data are collected. Comparisons will be made of Reynolds Creek runoff data with the Boise Front runoff data.

4. Erosion and Sediment

   a. On the Reynolds Creek Experimental Watershed, sediment yield data will be collected from two microwatersheds, one source watershed, two tributary, and two main stem sites. Bedload transport will be determined at six sites with sediment catchments or Helley-Smith samplers. Relationships of measured sediment transport to storm and channel factors for rainfall and snowmelt events will be studied. Sediment grain-size characteristics will be determined for selected runoff stations. Erosion and sediment yield data will be utilized to adapt and test prediction equations, such as the modified Universal Soil Loss Equation.

   b. On the Boise Front area, suspended and bedload material will be sampled on an event basis at four watershed sites. Sediment yield will be measured by establishing soil erosion sites on representative gullies, poorly vegetated hillslopes, and predominant range sites. Data will be collected to determine the factors of the Universal Soil Loss Equation. Actual soil losses will be measured from topographic surveys made after erosive storm events. If details can be arranged, an AR rainulator will be used to evaluate the USLE, C and K parameters.

5. Water Quality

   a. On the Reynolds Creek Experimental Watershed, bacteria determinations, DO, BOD, COD, and conductivity will be sampled at eight sites and complete chemical determinations at two sites on a regular schedule. Both the multiple tube and membrane filter methods will be used to determine bacterial concentrations associated with suspended sediment during major runoff events. Results will permit the separation of free coliform bacteria from those adsorbed on suspended sediment during runoff. Soil biological activity will be investigated to determine background coliform counts and survival of fecal coliforms on rangeland, following removal of cattle at the end of the grazing season. Information will be developed on sources of bacteria in streamflow under different soil, vegetative, climatic, and management conditions. Aquatic insect investigations will be conducted, if the watershed is sprayed for grasshoppers, and pesticide concentrations in the water will be determined. Rangeland management practices will be recommended that are consistent with

State water quality standards. An initial study will be made of available water quality models that might apply to Reynolds Creek data. The basis of selection will be a model that may be used with limited data to produce reasonable results.

b. On the Boise Front study area, water quality samples will be collected at six sites. Initial efforts will be to develop baseline water quality information, which represents the rest-rotation grazing system. Comparisons will be made with water quality data from grazing practices represented on the Reynolds Creek Watersheds.

1. PRECIPITATION

Personnel Involved

C. L. Hanson, Agricultural Engineer	Supervises the planning and design of precipitation studies; performs analyses and summarizes results.
V. M. Aaron, Hydrologic Technician	Responsible for data reduction and processing.
D. L. Coon and R. P. Morris, Hydrologic Technicians	Responsible for data collection, compilation, and assists with analyses.
R. L. Engleman, Mathematician	Responsible for data compilation and assists in analyses.

a. Reynolds Creek

(Reynolds Creek site locations on Introduction, Figure 1.)

The four precipitation sites listed in Table 1.a.1 represent the precipitation conditions that existed on the watershed. The annual precipitation varied from 0.3 inch above average at site 155X07 to 1.5 inches above average at sites 076X59 and 176X07. The winter (November through April) precipitation accounted for the above-average precipitation amounts, and varied from 2.7 inches above average at 076X59 to 5.3 inches above average at 176X07. The above-average precipitation was due to the heavy precipitation during November, December, February, and April. Summer (May through October) precipitation was below average at all sites, and varied from 1.2 inches at 076X59 to 3.8 inches at 176X07.

Wyoming Shielded Gage Study: A Wyoming shielded gage, note picture on front cover, was set up at precipitation gage site 127X07 to compare its catch to that of the dual-gage system. The Wyoming shield was developed to measure all precipitation, but specifically to increase the reliability of snowfall measurements under windy conditions. The 1978 water-year precipitation by months is shown in Table 1.a.2.

TABLE 1.a.2.--1978 water year dual gage and Wyoming shielded gage catches (inches) at site 127X07.

	Nov-April	May-Oct	Total
Dual gage	11.696	3.435	15.131
Wyoming gage	12.10	3.36	15.46

The Wyoming shielded gage catch was 15.46 inches, which was 2 percent, or 0.33 inch more than recorded by the dual gage. The Wyoming shielded gage catch was 3 percent greater than the dual gage for November through April, and 2 percent less for the months of May through October. These results indicate that the two gaging systems had very similar results. If the Wyoming shielded gage continues to

Table 1.a.1.--Water year precipitation (inches) at four locations on Reynolds Creek Watershed.[1/]

Site	Elevation	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
076X59	3965	1978	.210	1.891	1.885	.736	1.159	.945	2.783	.499	.839	.759	.480	.650	12.836
		1963-1978	.912	1.238	1.282	1.552	.781	.934	.960	.680	1.454	.304	.731	.507	11.335
116X91	4760	1978	.338	2.757	3.557	1.558	3.082	1.222	3.491	.870	1.112	.328	.658	.670	19.643
		1963-1978	1.532	2.149	2.500	2.721	1.405	1.729	1.802	1.103	1.681	.443	.693	.755	18.513
155X07	5410	1978	.429	4.849	6.147	2.738	3.638	1.810	4.870	.912	.926	.618	1.067	.974	28.978
		1963-1978	2.082	3.637	3.999	4.795	2.606	2.818	2.416	1.602	1.980	.646	1.078	.988	28.647
176X07	6760	1978	.653	7.188	8.249	5.589	6.444	2.781	7.645	1.104	.885	.657	1.123	1.505	43.823
		1963-1978	2.348	5.684	6.307	8.322	4.358	4.255	3.659	2.210	2.354	.594	1.098	1.103	42.292

[1/] Rain gage locations are shown on Introduction, Figure 1.

catch the same amount of precipitation as the dual-gage system, it would be the shield to install, because there is only one gage to maintain and one record to process. It is apparent that the ink trace on the Wyoming shielded gage chart shows much less oscillation from wind; thus, data processing is easier.

Annual and Monthly Precipitation Model: Determining the average annual and monthly precipitation amounts and their variation is basic to many hydrologic and natural resource studies. Most of the rain gages in the Rocky Mountain Region are located in the valleys and do not represent the average conditions on a watershed. This is mainly due to the relationship between precipitation and elevation, with the higher elevations generally receiving the most precipitation.

The objective of this study is to develop a model that does not require complicated statistical procedures or large computer facilities, but still has utility in hydrologic and natural resource studies. This first effort, utilizing the record of the Reynolds Creek Watershed, is to model annual and monthly precipitation, incorporating the elevation component. The procedures developed in this model would then be used to develop a model for representative areas in Idaho and surrounding states.

The basic equation adapted from Clarke (1973)[1/] is:

$$P = e^{(\mu + \sigma y)} \qquad (1)$$

where, P is either annual or monthly precipitation, e is the natural log, μ is either average annual precipitation or average monthly precipitation, σ is annual or monthly standard deviation, and y is a pseudo-random normal deviate (from N (0,1)).

[1/] Clarke, R. T. 1973. Mathematical Models in Hydrology. Irrigation and Drainage Paper 19. Food and Agriculture Organization of the United Nations, Rome. 282 p.

The objective of this study is to be able to generate a record for a watershed, so equations are required that relate precipitation amount and standard deviation to elevation. The following average precipitation-elevation relationships were developed to represent the east and west sides of the watershed.

$$\text{(East)} \qquad \mu_e = e^{(4.621\text{x}10^{-4}X + 0.685)} \qquad (2)$$

$$\text{(West)} \qquad \mu_w = e^{(4.640\text{x}10^{-4}X + 0.471)} \qquad (3)$$

where, μ_e and μ_w are the average annual precipitation on the east and west sides, respectively, and X is elevation in feet. There were separate equations developed for the east and west sides separately, because the major winter storms move over the watershed from southwest through northwest to the east, and the high elevations on the south and west sides of the watershed receive more precipitation than areas on the north and east side at the same elevation. This precipitation difference at the same elevation can be expected in mountainous areas, and may have to be taken into account when the precipitation for an entire watershed is generated.

The equation developed to represent the annual precipitation standard deviation to elevation relationship is:

$$\sigma = e^{(3.760\text{x}10^{-4}X - 0.526)} \qquad (4)$$

When Equation 1 is used to generate monthly precipitation, μ is the average precipitation for the months that had precipitation and not the overall average. Because not all summer months (for example, July) have precipitation every year, parameter A is used to account for the percent of years that the month in question had precipitation out of a station record.

The following procedure outlines how Equation 1 would be used to generate a precipitation record for a location.

Annual precipitation generation:

1. Compute the average annual precipitation, μ, for the station, (Equations 2 and 3).

2. Compute the standard deviation, σ, for the station, (Equation 4).

3. Generate the desired (example, 50 years) record length by obtaining the necessary number of random numbers, y, and solving Equation 1. The random number can be generated by most computer center statistical routines. Equation 1 can also be solved very easily by using tables of random numbers and a hand calculator.

Monthly precipitation generation:

1. Compute the average monthly, μ, precipitation, using only the years that the month in question had precipitation. This will always be equal to or greater than the average over <u>all</u> months.

2. Compute the standard deviation, σ, using the years that the month in question had precipitation.

3. Compute A by dividing the number of years when the month in question had measurable precipitation by the total years of record.

4. The monthly generation procedure is basically the same as the annual generation procedure; however, the first step for each year's generation is to obtain a random number from a uniform distribution to determine if there is monthly precipitation on the year being generated. This is done by obtaining the uniform random number from either a computer center procedure or a random numbers table. If the random number is larger than A, there is no precipitation that year; and if the random number is equal to or smaller than A, there is precipitation.

5. If the procedure in step 4 indicates that there is precipitation, then the amount is generated, using Equation 1 and the same procedures outlined in step 3 for annual precipitation.

6. When monthly precipitation is generated, the annual amount is the sum of the monthly amounts.

Table 1.a.3 shows the results of 50-year simulations at two sites, 076X59 and 163X20. As can be seen, the average, standard deviation, and range were very well simulated.

Development of the relationships between monthly precipitation and elevation are being done at the present time. Table 1.a.4 shows a 50-year simulation for January and July at site 076X59. As can be seen, the simulation was very good for January, but not as good for July. The July simulation overestimated the number of dry Julys; and, thus, the average value was low.

This project is continuing and will be expanded to include Idaho and surrounding areas.

TABLE 1.a.3.--A 50-year simulation of the average annual precipitation at two sites on the Reynolds Creek Watershed.

	076X59		163X20	
	MEASURED (15 YRS)	SIMULATED (50 YRS)	MEASURED (15 YRS)	SIMULATED (50 YRS)
	----------------------------	-------------*inches*-------------	----------------------------	
AVERAGE	11.17	11.19	43.86	43.89
STANDARD DEVIATION	2.27	2.33	7.92	7.54
RANGE	6.88-14.63	5.28-16.41	32.66-57.95	23.70-60.34

TABLE 1.a.4.--A 50-year simulation of the average monthly precipitation for January and July at site 076X59.

	JANUARY		JULY	
	MEASURED (15 YRS)	SIMULATED (50 YRS)	MEASURED (15 YRS)	SIMULATED (50 YRS)
	----------------------------	-------------*inches*-------------	----------------------------	
AVERAGE	1.60	1.57	0.27	0.21
STANDARD DEVIATION	1.24	1.13	0.29	0.53
RANGE	0.34-4.16	0.30-5.07	0.00-1.04	0.00-3.08
A	1.00	1.00	0.73	0.66

b. Boise Front

(Boise Front Watershed site locations on Introduction, Figure 2.)

The 1978 water year precipitation for the four sites on the Boise Front and the Boise Airport are listed in Table 1.b.1. The 1977-78 average amounts at the four sites on the Boise Front and 38-year average at the Boise Airport are also listed in the table. As can be seen, 1978 precipitation was much above the 1977-78 average at all sites. At the Boise Airport, annual precipitation was 26 percent above average, and winter (November-April) precipitation was 59 percent above average.

Table 1.b.1.--Water year precipitation (inches) at four locations on the Boise Front, and the Boise Airport.

Site	Elevation	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
328X86[1]	2880	1978	.220	2.109	2.885	2.130	2.267	1.326	3.239	.620	.900	.660	.200	2.010	18.566
		1977-1978						1.101	1.709	1.255	1.826	.534	.590	1.450	
322X62	3800	1978	.262	2.493	3.544	2.850	3.494	2.411	4.053	.578	1.092	.711	.194	2.109	23.791
		1977-1978	.530	1.267	1.880	1.923	2.427	1.885	2.251	1.584	1.965	.580	.452	1.663	18.407
314X50	4650	1978	.290	3.427	4.644	3.671	3.830	2.801	4.181	.557	1.384	1.148	.320	2.208	28.461
		1977-1978	.534	1.787	2.496	2,709	2.557	2.449	2.355	1.838	2.226	.844	.629	1.857	22.281
311X94	5450	1978	.360	3.272	4.988	2.725	3.548	2.669	5.788	.636	1.339	1.121	.310	2.714	29.470
		1977-1978	.681	1.760	2.698	1.967	2.907	2.652	3.197	2.036	1.926	.805	.685	2.022	23.336
Boise Airport	2838	1978	.21	1.86	2.46	2.37	1.50	1.43	2.34	.36	.56	.48	.24	.89	14.70
		1941-1978	.85	1.33	1.38	1.47	1.14	1.06	1.13	1.17	1.04	.22	.31	.54	11.64

[1] Gage installed February 1977.

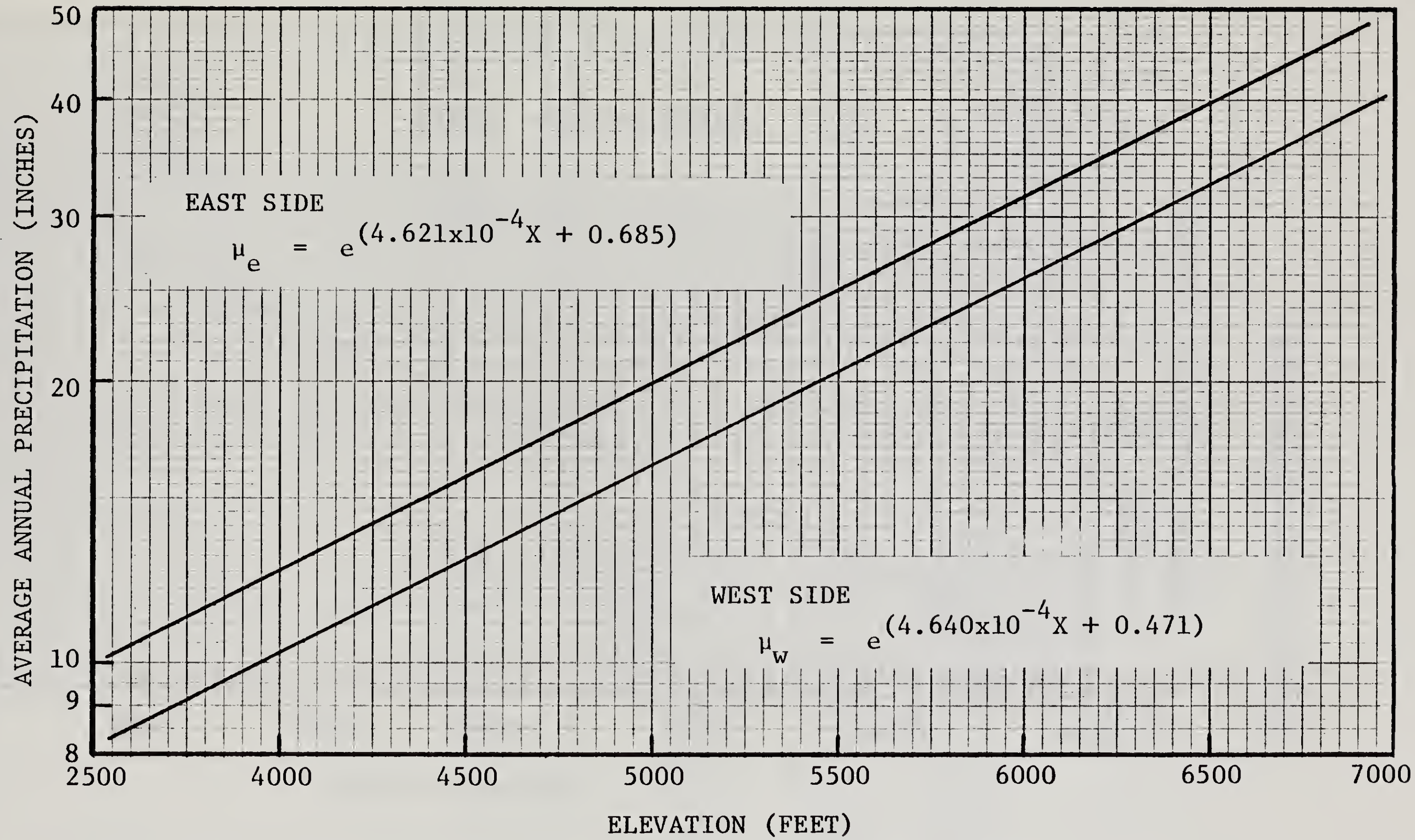

Figure 1.a.1.--Average annual precipitation versus elevation.

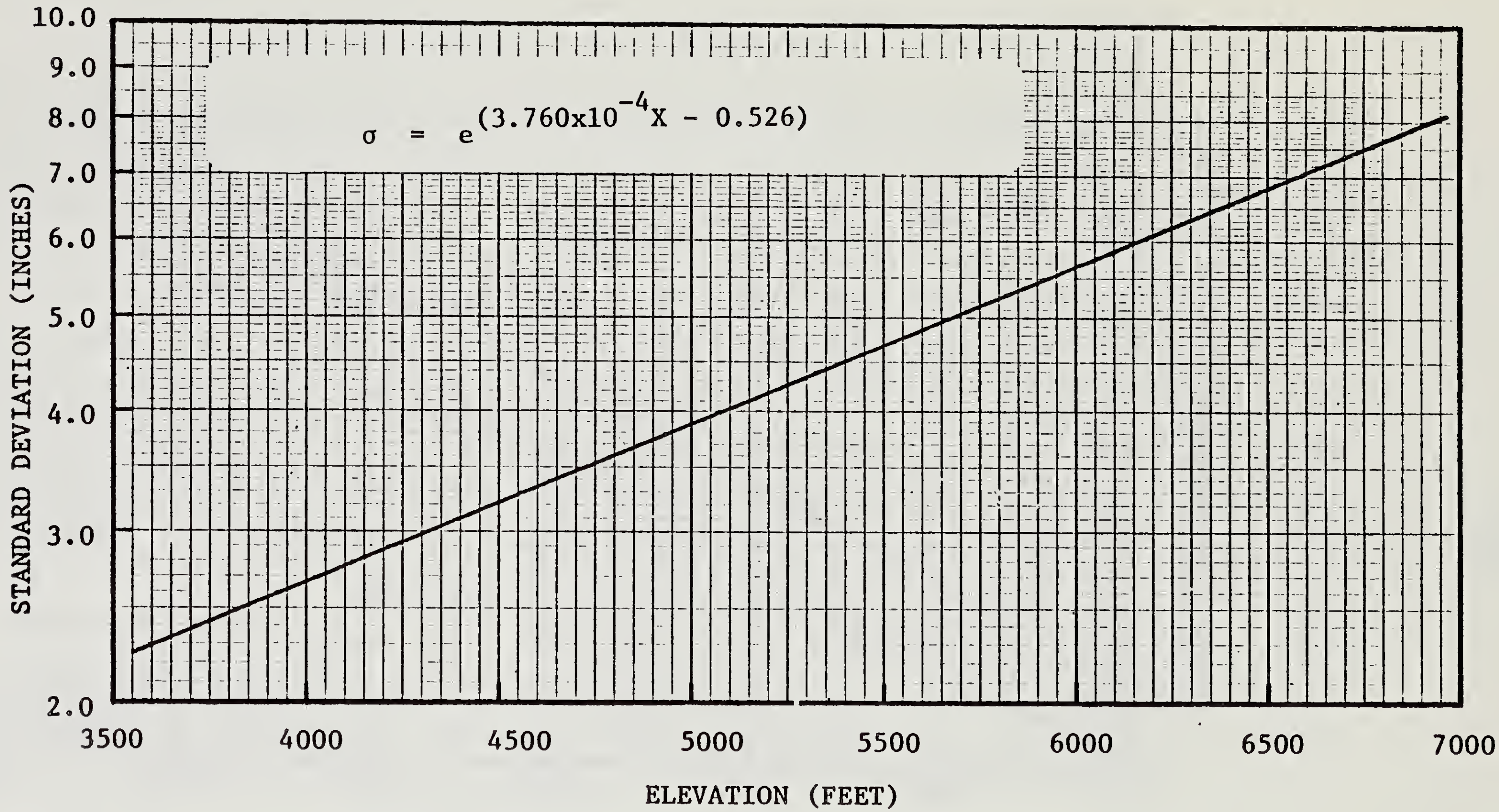

Figure 1.a.2--Standard deviation of average annual precipitation versus elevation.

2. VEGETATION

Personnel Involved

G. A. Schumaker, Soil Scientist	Plan, design, supervise field studies, and coordinate research activities and prepare reports.
C. L. Hanson, Agricultural Engineer	Perform computer analyses relative to field studies and assist in planning field studies.
D. L. Coon, Hydrologic Technician	Assist in data collection and noting field observations, including soil moisture measurement and calibration.
J. P. Smith, Hydrologic Technician	Assist in vegetation data reduction.
N. J. Phillips, Range Technician (temporary)	Assist in vegetation data collection and reduction.

a. Reynolds Creek

Herbage yield: Grazed and untreated (no grazing) herbage yields were obtained at the eight sites shown on Figure 2.a.1. Descriptive information for these sites is given in Table 2.a.1. These data are presently being processed and will be used to evaluate the effect of excluding grazing since 1971. These data will also be used to develop a herbage yield model.

Basal cover for 1978: Basal cover on eight study sites for the 1978 growing season are listed in Table 2.a.2. The average grass cover was greater on the untreated (no grazing) treatment than on the associated grazed areas; however, this difference was because of very large differences at only three locations. On six of the eight plots, there was more forb cover on the grazed than the ungrazed plot. There was less bare ground on all untreated plots than on the associated grazed areas. The average bare ground on the untreated plots was significantly less ($P<0.05$) than on the grazed areas.

Basal and canopy summary for 1972 through 1978: One of the reasons for establishing the grazing study areas in 1971 on the Reynolds Creek Watershed was to find out what effect excluding grazing would have on range condition. Tables 2.a.3 and 2.a.4 are summaries of basal and canopy cover of selected species at each of the nine study sites for the period 1972 through 1978. These data are based on 700 points per treatment, untreated (no grazing) and grazed, at each site each year. A basal vegetation hit was recorded only if the pin hit a live plant at the point of emergence from the ground. A canopy cover hit was recorded when the pin made contact with the canopy cover. Only one contact was recorded per species per pin, with a limit of three species per pin. At the Upper Sheep Creek (dense) and Reynolds Mountain (dense) sites, there were a few points per plot when there were actually four or five species hit per pin, but only the first three hits from the top were recorded.

As can be seen from these tables, no trend toward improved cover had developed due to fencing the plots. In general, there is more grass cover on the untreated plots, but there is no trend toward improved condition. The year-to-year differences are great and this may tend to cover up any small trends with only seven years of record.

The forb and brush cover at each site does not show any trend toward improved range condition due to fencing. The sagebrush kill during the winter of 1976 and 1977 is very evident in the canopy cover data in the Upper Sheep (dense) and the Reynolds Mountain (dense) sites (Figure 2.a.1).

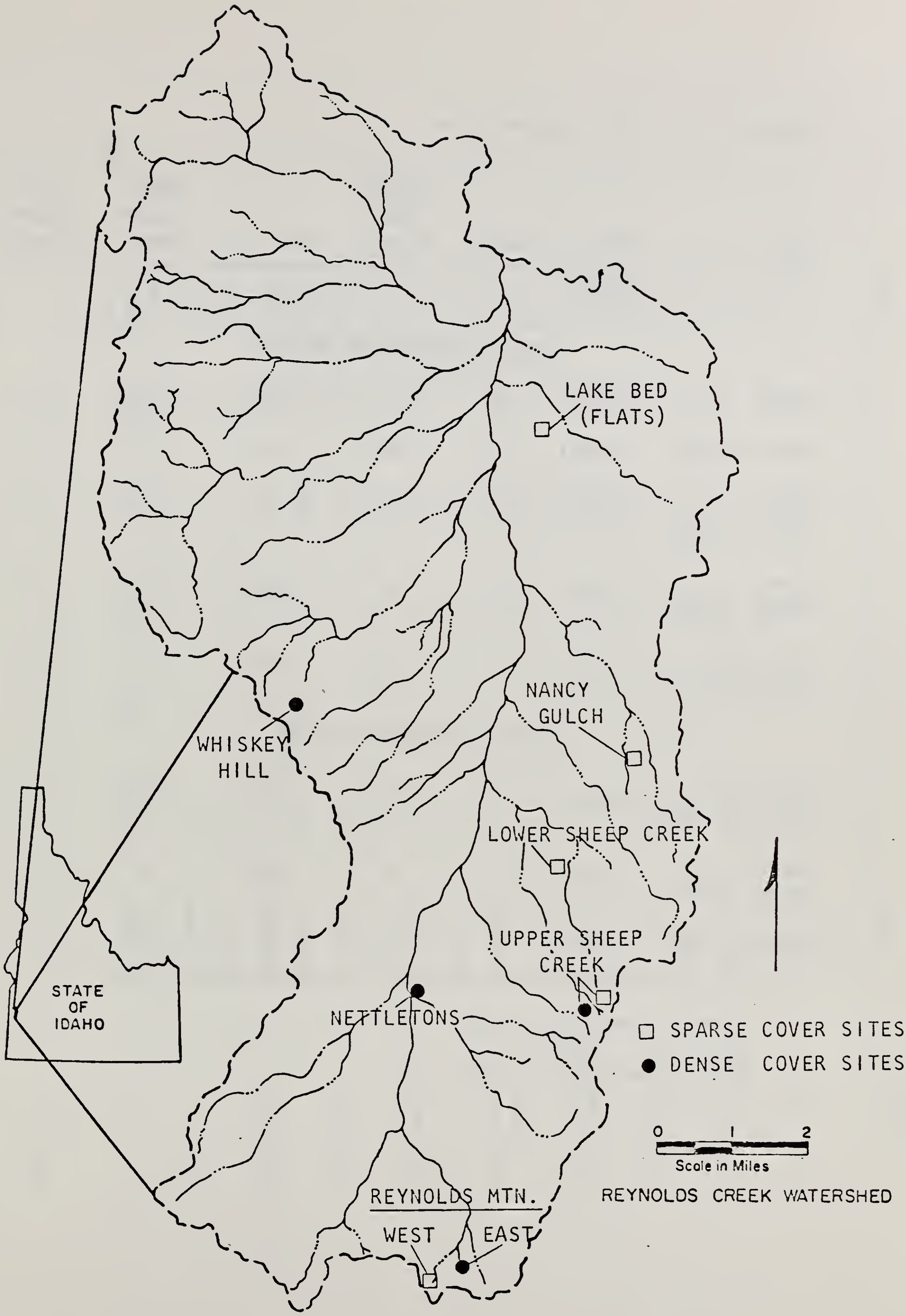

Figure 2.a.1.--Location of study sites.

TABLE 2.a.1.--Site information.

Site	Ele.	Slope	Aspect of Slope	Precip.	Vege- tative Cover	SCS Hydro. Class.
	feet	%		*ins.*	%	
			Sparse Vegetation Sites			
Flats	4000	5	N	10	25	B
Nancy Gulch	4600	8	NE	12	25	C
Lower Sheep Creek	5400	16	NW	14	25	B
Upper Sheep Creek	6100	33	SW	20[1/]	25	D
Reynolds Mountain West	6850	5	SW	43[1/]	25	B
			Dense Vegetation Sites			
Reynolds Mountain East	6800	6	NW	43[2/]	50	B
Upper Sheep Creek	6100	33	NE	20[2/]	50	C
Whiskey Hill	5500	15	E	23	50	B

[1/] Snow removed by wind.

[2/] Snow deposition zone.

TABLE 2.a.2.--Basal Cover from eight study sites on Reynolds Creek Watershed in 1978.

Site	Treatment	% Grasses	% Forbs	% Shrubs	% Litter	% Rock	% Bare Ground
Flats	Untreated	20.7	0.7	1.1	19.5	5.8	52.2
	Grazed	8.7	1.4	1.7	14.1	12.3	61.8
Whiskey Hill	Untreated	7.6	2.0	0.6	58.6	4.4	26.8
	Grazed	5.6	2.4	1.8	50.8	5.8	33.6
Nancy Gulch	Untreated	8.3	12.6	1.4	19.0	19.9	38.8
	Grazed	9.1	8.8	1.0	19.3	19.8	42.0
Lower Sheep Creek	Untreated	8.3	3.3	2.0	34.5	28.5	23.4
	Grazed	12.8	3.4	3.0	25.9	30.9	24.0
Upper Sheep Creek (sparse)	Untreated	7.3	0.9	2.0	24.1	31.6	34.1
	Grazed	7.2	1.2	2.0	18.5	32.6	38.5
Upper Sheep Creek (dense)	Untreated	24.1	8.0	0.8	63.4	0.4	3.3
	Grazed	9.2	10.7	0.8	60.9	0.8	17.6
Reynolds Mountain (sparse)	Untreated	5.1	6.5	0.5	22.2	49.3	16.4
	Grazed	6.1	9.4	0.1	29.6	38.1	16.7
Reynolds Mountain (dense)	Untreated	10.4	3.8	0.6	69.4	2.4	13.4
	Grazed	3.0	3.4	0.2	75.0	2.8	15.6
1978 AVERAGE	Untreated	11.5	4.7	1.1	38.8	17.8	26.1[1/]
	Grazed	7.7	5.1	1.3	36.8	17.9	31.2

1/ The grazed treatment average bare ground was significantly greater ($P<0.05$) than the untreated treatment.

TABLE 2.a.3.--Basal cover of selected species from nine study sites on Reynolds Creek Watershed, 1972-1978.

Site	Treatment	Species	72	73	74	75	76	77	78
Flats	Untreated	Bottlebrush squirreltail	2.6	0.3	2.4	1.6	0.3	2.7	1.9
		Cheatgrass	8.1	2.1	14.8	15.3	0.1	0.3	18.7
		Shadscale	----	0.9	1.0	0.6	0.1	2.4	1.1
	Grazed	Bottlebrush squirreltail	4.1	0.1	1.7	1.0	----	2.0	0.4
		Cheatgrass	7.7	1.7	7.3	14.1	0.7	0.3	8.3
		Shadscale	0.1	0.7	1.2	1.1	----	0.4	0.7
Whiskey Hill	Untreated	Bottlebrush squirreltail	2.0	----	1.6	2.0	0.3	4.2	0.6
		Sandberg bluegrass	5.0	2.7	3.6	1.2	1.3	3.0	1.8
		Big sagebrush	0.3	2.4	0.8	0.2	0.4	0.8	0.6
	Grazed	Bottlebrush squirreltail	3.3	3.3	1.6	2.0	0.7	2.4	0.8
		Sandberg bluegrass	9.9	10.4	3.2	6.4	1.4	4.8	2.8
		Big sagebrush	0.3	0.4	1.6	2.0	2.1	2.4	1.8
Nancy Gulch	Untreated	Bottlebrush squirreltail	2.7	0.8	1.7	1.7	0.4	1.4	1.0
		Sandberg bluegrass	8.9	10.4	16.0	9.5	2.6	3.9	7.3
		Big sagebrush	----	0.5	0.7	1.4	0.3	2.0	1.4
	Grazed	Bottlebrush squirreltail	2.4	0.2	1.0	0.6	----	0.4	0.1
		Sandberg bluegrass	14.9	6.2	13.3	11.0	2.6	3.3	8.9
		Big Sagebrush	0.1	0.8	0.9	1.0	0.3	1.6	1.0
Lower Sheep Creek	Untreated	Sandberg bluegrass	13.9	NA	17.7	12.0	3.9	29.9	7.9
		Low sagebrush	0.4	NA	2.6	6.0	1.0	1.3	1.9
	Grazed	Sandberg bluegrass	14.7	NA	16.9	15.0	5.9	29.2	12.6
		Low sagebrush	0.1	NA	1.7	4.4	0.7	2.1	3.0
Upper Sheep Creek (sparse)	Untreated	Sandberg bluegrass	12.1	NA	7.0	5.3	3.4	11.3	6.9
		Low sagebrush	1.1	NA	1.9	9.1	1.1	7.1	1.9
	Grazed	Sandberg bluegrass	8.1	NA	5.7	3.4	3.0	8.6	7.0
		Low sagebrush	0.4	NA	2.3	4.0	0.7	4.0	1.3
Upper Sheep Creek (dense)	Untreated	Bottlebrush squirreltail	9.6	2.1	6.6	1.0	0.4	3.2	4.4
		Needlegrass	8.6	3.5	3.6	1.6	0.2	1.3	3.1
		Big sagebrush	----	2.3	2.9	0.1	----	0.4	0.7
	Grazed	Bottlebrush squirreltail	8.8	1.7	2.3	0.2	----	1.9	2.0
		Needlegrass	10.0	3.6	1.4	2.6	----	0.6	2.6
		Big sagebrush	----	2.9	1.0	2.8	----	0.3	0.3
Reynolds Mountain (sparse)	Untreated	Sandberg bluegrass	----	NA	0.1	----	0.9	3.7	0.4
		Sedge	4.1	NA	1.9	4.3	7.9	0.3	1.7
		Idaho fescue	3.1	NA	1.7	2.4	1.1	4.4	2.6
		Big sagebrush	----	NA	0.7	2.6	1.0	----	0.4
	Grazed	Sandberg bluegrass	----	NA	----	----	----	6.0	2.1
		Sedge	3.0	NA	----	2.7	6.1	0.3	1.9
		Idaho fescue	1.1	NA	2.1	2.1	2.3	1.6	0.1
		Big sagebrush	----	NA	0.9	3.9	0.6	----	0.1
Reynolds Mountain (dense)	Untreated	Needlegrass	4.6	4.0	2.0	2.0	0.3	0.8	2.4
		Bluegrass	2.8	1.7	----	0.2	0.5	3.8	3.2
		Big mountain brome	3.6	4.2	1.2	0.6	1.0	2.4	1.2
		Lupine	6.3	4.0	2.0	1.4	13.1	0.4	0.2
		Big sagebrush	----	4.0	0.8	3.4	2.8	0.2	0.6
	Grazed	Needlegrass	1.9	----	1.2	5.0	2.3	0.4	0.2
		Bluegrass	4.0	1.3	1.2	1.0	1.8	1.0	0.2
		Big mountain brome	5.0	0.4	1.6	1.4	2.3	1.4	0.8
		Lupine	2.1	0.8	2.2	1.2	12.4	0.2	0.4
		Big sagebrush	0.1	3.4	0.6	3.2	0.8	0.2	----
Nettleton	Untreated	Bottlebrush squirreltail	2.6 1/	3.0	2.6	0.4	1.0	2.0	1.0
		Sandberg bluegrass	10.1	13.4	14.7	12.3	2.6	10.1	2.9
		Cheatgrass	11.3	5.4	8.1	23.9	0.7	10.1	3.9
		Big sagebrush	----	----	0.6	1.4	0.6	1.0	0.7
	Grazed	Bottlebrush squirreltail	2.6 1/	3.2	0.4	0.4	0.4	3.0	1.3
		Sandberg bluegrass	10.1	21.0	9.4	13.2	3.0	14.0	14.7
		Cheatgrass	11.3	4.7	0.4	5.3	----	4.0	2.9
		Big sagebrush	----	0.5	0.3	2.1	0.9	1.0	0.9

1/ Cover data taken before grazing study started.

TABLE 2.a.4.--Canopy cover of selected species from nine sites on Reynolds Creek Watershed, 1972-1978.

Site	Treatment	Species	72	73	74	75	76	77	78
Flats	Untreated	Bottlebrush squirreltail	1.0	2.8	5.8	5.0	3.4	3.3	7.8
		Cheatgrass	25.2	30.0	20.0	21.1	45.8	0.3	27.5
		Shadscale	11.9	9.6	7.6	4.4	7.8	9.7	8.4
	Grazed	Bottlebrush squirreltail	0.7	0.6	3.3	1.5	0.3	1.4	1.4
		Cheatgrass	18.6	16.0	10.6	23.5	47.4	0.1	13.7
		Shadscale	13.6	9.2	7.0	3.4	6.7	5.5	6.7
Whiskey Hill	Untreated	Bottlebrush squirreltail	1.0	0.2	6.4	4.4	5.2	5.0	7.6
		Sandberg bluegrass	4.4	3.7	4.8	3.0	9.1	1.8	2.8
		Big sagebrush	39.8	29.0	14.8	27.4	17.6	20.8	14.2
	Grazed	Bottlebrush squirreltail	1.2	1.4	6.6	3.4	4.7	4.6	5.2
		Sandberg bluegrass	4.4	4.3	5.2	5.8	4.3	3.8	4.6
		Big sagebrush	40.4	30.8	15.8	30.0	29.2	26.4	19.6
Nancy Gulch	Untreated	Bottlebrush squirreltail	2.8	2.7	4.0	3.9	3.8	1.7	4.3
		Sandberg bluegrass	17.1	14.9	16.9	28.5	45.2	3.7	14.9
		Big sagebrush	18.3	15.7	8.4	12.3	9.9	10.9	10.2
	Grazed	Bottlebrush squirreltail	1.2	0.9	1.0	1.2	2.3	0.5	0.8
		Sandberg bluegrass	19.0	11.2	13.2	27.8	37.2	3.6	15.7
		Big sagebrush	17.8	12.6	9.4	13.0	12.6	9.5	6.7
Lower Sheep Creek	Untreated	Sandberg bluegrass	20.0	NA	15.5	19.0	30.2	21.1	10.5
		Low sagebrush	30.0	NA	19.3	26.1	28.8	16.3	23.9
	Grazed	Sandberg bluegrass	21.5	NA	14.1	15.6	38.4	16.6	11.5
		Low sagebrush	25.9	NA	19.5	25.1	24.4	21.4	21.9
Upper Sheep Creek (sparse)	Untreated	Sandberg bluegrass	14.5	NA	9.4	9.6	22.1	10.7	11.7
		Low sagebrush	24.9	NA	19.8	18.7	23.3	23.3	22.6
	Grazed	Sandberg bluegrass	9.5	NA	6.0	8.7	19.5	11.6	13.2
		Low sagebrush	18.7	NA	13.6	17.3	16.2	19.0	18.5
Upper Sheep Creek (dense)	Untreated	Bottlebrush squirreltail	6.0	4.6	9.5	6.9	4.4	14.4	15.7
		Needlegrass	2.1	5.8	5.3	5.8	2.4	4.2	9.5
		Big sagebrush	47.4	30.4	29.9	30.5	37.2	8.2	7.1
	Grazed	Bottlebrush squirreltail	2.1	1.1	1.7	0.8	0.4	3.5	8.2
		Needlegrass	1.2	3.0	0.8	3.4	1.2	2.5	4.7
		Big sagebrush	45.8	25.2	35.0	38.2	39.4	4.9	3.2
Reynolds Mountain (sparse)	Untreated	Sandberg bluegrass	----	NA	0.1	----	----	3.3	2.0
		Sedge	5.1	NA	3.0	4.1	9.4	0.7	3.8
		Idaho fescue	4.2	NA	3.2	3.6	2.0	3.5	8.9
		Big sagebrush	22.7	NA	14.3	17.0	18.6	9.4	9.4
	Grazed	Sandberg bluegrass	----	NA	----	----	----	6.2	4.8
		Sedge	4.2	NA	----	2.5	5.3	0.4	2.9
		Idaho fescue	2.9	NA	2.1	3.5	4.4	1.7	6.1
		Big sagebrush	22.4	NA	10.3	15.1	22.2	8.9	7.8
Reynolds Mountain (dense)	Untreated	Needlegrass	2.3	0.8	2.4	4.8	0.8	2.0	6.0
		Bluegrass	0.8	0.6	----	1.2	1.8	5.0	5.6
		Big mountain brome	1.3	1.3	1.6	2.2	5.9	11.2	15.0
		Lupine	7.8	11.2	10.4	11.4	12.0	8.0	11.2
		Big sagebrush	59.4	48.2	45.6	42.2	58.6	10.6	16.0
	Grazed	Needlegrass	2.3	0.6	1.0	5.8	1.0	1.0	3.4
		Bluegrass	2.3	1.0	1.2	2.0	1.0	4.8	3.8
		Big mountain brome	4.4	1.5	2.8	1.8	2.3	20.0	30.0
		Lupine	4.1	9.0	8.8	8.6	11.6	18.0	7.8
		Big sagebrush	48.4	43.0	32.2	49.2	61.0	6.4	7.8
Nettleton	Untreated	Bottlebrush squirreltail	6.6[1/]	4.1	6.7	0.7	7.3	4.0	8.1
		Sandberg bluegrass	18.9	19.3	20.5	26.1	28.0	9.1	8.7
		Cheatgrass	16.1	7.7	17.6	25.1	20.2	29.3	49.6
		Big sagebrush	11.1	0.5	5.7	6.6	8.4	6.1	5.2
	Grazed	Bottlebrush squirreltail	6.6[1/]	2.0	1.8	1.3	4.5	3.0	5.9
		Sandberg bluegrass	18.9	17.1	10.0	31.0	50.3	14.0	45.8
		Cheatgrass	16.1	1.5	5.0	8.8	6.9	15.0	20.0
		Big sagebrush	11.1	5.5	5.3	12.9	6.0	7.0	6.3

[1/] Cover data taken before grazing study started.

Soil Surface factor ratings: The Soil Surface Factor (SSF) rating sheet, Form 7310-12, has been used in estimating erosion on the grazed and exclosure treatments at the nine study sites since they were initiated in 1971 and 1972. Table 2.a.5 lists the numeric total for seven erosion factors for each treatment at each study site for the years that data were available. Observations included in the rating are soil movement, surface litter, surface rock, pedestalling, flow patterns, rills, and gullies.

A statistical analysis has been completed for each site. With the exception of two sites, there was no statistical difference between the SSF values for the grazed and exclosure treatments. At the Flats site, the SSF value for the grazed treatment showed a significantly higher erosion potential ($P<0.05$) than the exclosure; however, both means remained in the Erosion Class of Stable.

In 1975, the SSF ratings for the treatments at the Whiskey Hill site were in the Moderate Erosion Class (41-60) when ratings were taken following an intense storm. SSF averages for the 1972 through 1978 period were 23 and 19 for the grazed and exclosure treatments, respectively.

The SSF means at the Nancy Gulch site were 27 and 22 for the grazed and exclosure treatments, respectively; the difference between these means was not significant. Ratings in 1975 were completed after an intense storm; and, while rills and flow patterns were recent on both treatments, the erosion class was rated as Slight.

The SSF ratings were not significantly different at several sites, such as Upper Sheep (sparse), Upper Sheep (dense), and Reynolds Mountain (sparse), but the exclosure rating was always less or equal to the grazed area rating. This would suggest that with more years of record, the SSF on the grazed areas may be significantly greater than on the ungrazed plots.

At the Nettleton site, the SSF means of 17 and 9 for the grazed and exclosure treatments, respectively, were significantly different ($P<0.05$) and are discussed in the section devoted to the Nettleton study site.

TABLE 2.a.5.-- Soil surface factor ratings (SSF) from nine study sites on Reynolds Creek watershed, 1971-1978.

Site	71		72		73		74		75		76		77		78		Average	
	EU[1/]	GR	EU	GR	EU	GR	EU	GR	EU	GR	EU	GR	EU	GR	EU	GR	EU	GR
Flats	13	20	20	24	13	14	17	20	7	13	5	13	14	20	21	27	14	19[2/]
Whiskey Hill	--	--	21	15	11	21	4	15	39	49	18	18	22	21	NA	NA	19	23
Nancy Gulch	28	37	NA[3/]	23	28	34	22	25	23	29	17	27	20	20	13	22	22	27
Lower Sheep	36	46	NA	NA	44	24	25	21	13	18	14	16	19	20	18	20	24	24
Upper Sheep (sparse)	44	45	NA	NA	42	44	34	37	21	24	18	18	20	23	26	32	29	32
Upper Sheep (dense)	5	13	NA	NA	7	12	3	8	NA	NA	11	11	8	8	4	6	6	8
Reynolds Mtn. (sparse)	NA	17	14	15	13	15	17	18	14	23	12	15	23	25	9	11	15	17
Reynolds Mtn. (dense)	8	6	NA	NA	7	10	0	7	NA	NA	4	9	2	7	3	4	4	7
Nettleton	11	15	14	15	10	14	7	22	3	15	5	14	10	26	11	18	9	17[2/]

1/ EU = untreated; GR = grazed.
2/ The grazed treatment SSF values were significantly greater ($P<0.05$) at the Flats and Nettleton sites.
3/ Not available.

Nettleton study site: The effects of heavy grazing since 1971 at the Nettleton study site were again very striking. The study site had good management prior to 1971 when heavy grazing was imposed on one of the treatments, while the adjacent exclosure received no use. Cattle were turned into the grazed area on June 11, and were removed 10 days later when the major species showed at least 80 percent utilization. Randomly placed caged plots served as harvest areas, since harvest was completed after cattle had grazed the area. Total production on the grazed site averaged 1,015 pounds per acre, compared to 1,850 pounds per acre from the exclosure. Nonsage yields, or the portion primarily consumed by cattle, averaged 630 pounds per acre, while yields from the exclosure averaged 1,560 pounds per acre, or more than twice the yield from the plot where the effects of grazing were being observed.

Nonsage yields from the grazed plot also indicate that the livestock were forced to utilize the area heavily in order to meet their forage requirements. Feed requirements for the 12 animal units grazing the area for the 10-day period are estimated at 3,000 pounds. Nonsage forage production for the 6.33-acre grazed plot is estimated at 3,980 pounds, based on an average yield of 629 pounds per acre. While cattle were not weighed before and after the grazing period, it appeared that their weight was more than maintained. While more forage was available for use than would be needed to meet animal requirements, it is recognized that not all of the forage produced was available for livestock consumption.

Cover measurements were taken at this study and are reported in Tables 2.a.3 and 2.a.4. There was a good accumulation of litter on both grazed and exclosure areas. Average Soil Surface Factor rating values from 1971 through 1978 were 17 and 9 for the grazed and ungrazed treatments, respectively, and were significantly different, ($P<0.05$) (Table 2.a.5). While values for both treatments still show an Erosion Class of Stable, the amount of bare ground has increased on the grazed treatment.

Soil water data: Soil water data were collected during the grazing season at five sites on the Reynolds Creek Watershed during 1978. These data are being processed at the present time. There was only limited progress made toward developing a soil water depletion model. Soil water depletion curves have been developed from four years of data at five sites.

Herbage yield model: After an extensive literature review, the decision was made to adapt the procedures outlined by Sneva and Hyder (1962)[1/], which relates median herbage yield to median effective precipitation. This procedure has been used in semiarid areas and the results can be extrapolated to other areas.

Preliminary analyses indicate that the annual herbage yield is related to effective precipitation at a specific location. At locations that are below about 5500 feet, the sum of the precipitation for the months of November through one month before harvest relates best with herbage yield. At locations above about 5500 feet, two separate precipitation seasons have to be taken into account. The first period is the snow accumulation season, and the second period is the spring rain and snow. The 1978 herbage yield data is being incorporated into the study at the present time. This study is scheduled for completion during FY 79.

PLANT MATERIALS NURSERIES

Plantings in the three Reynolds Creek nurseries were given ratings of Good, Fair, or Excellent during the 1978 season and are shown in Table 2.a.6. The sites are at Flats, Nancy Gulch, and Reynolds Mountain. Rating of many of the entries showed improvement and good recovery over the previous year. In 1977, drought affected spring and summer growth at the Flats and Nancy Gulch sites, while some stands at the Reynolds Mountain site were reduced because of winter kill.

Flats: The number of grasses showing establishment at the Flats (10-inches precipitation annually) site is small, but they hold an Excellent rating. Crested wheatgrass (*Agropyron desertorum*), intermediate wheatgrass (*Agropyron intermedium*), pubescent wheatgrass (*Agropyron trichophorum*), and tall wheatgrass (*Agropyron elongatum*) selections had a rating of Excellent and showed improvement over the ratings for previous years. Russian wildrye (*Elymus junceus*) is slow to become established, but continued to improve. Flax (*Linum lewisii*) the only forb entry surviving at this site, continued to look good.

[1/] Sneva, F. A. and D. N. Hyder. 1962. Estimating herbage production on semiarid ranges in the intermountain region. J. Range Mgmt. 15(2):88-93.

Nancy Gulch: At the slightly-higher-precipitation-Nancy Gulch site (12 inches annually), most wheatgrass (*Agropyron*) species selections received Good or Excellent ratings. Stands of two intermediate wheatgrass selections, Greenar and Amur, showed some loss following the 1977 drought. Northern bromegrass (*Bromus inermis*) received an Excellent rating and two selections of orchardgrass (*Dactylis glomerata*), Yugoslavia PI251112 and the Ephrain dryland form, improved from previous ratings. Russian wildrye and hard sheep fescue (*Festuca oviua duriuscula*) improved in the 1978 ratings. Among the forbs, flax was given an Excellent rating and numerous alfalfa (*Medicago sativa*) plantings earned the rating of Good. Several of the brush selections, including the Moffet Co., Colorado bitterbrush (*Purshia tridentata*), continued to improve. The stands of Boise and Washoe County, Nevada, bitterbrush have not survived.

Reynolds Mountain: At the cool moist Reynolds Mountain site (43 inches annually), most grass species were rated Excellent. However, the pubescent wheatgrass selections are not adapted to the cool climate. Among the forbs, several birdsfoot deervetch selections (*Lotus corniculatus*) were Excellent. Rambler was the only alfalfa selection rated Excellent. Other plantings lacked uniformity and showed less vigor. Some winter kill probably occurred in the winter of 1976-77. Vaseyana sagebrush (*Artemisia tridentata vaseyana*), snowbrush (*ceanothus velutinous*), and bitterbrush were all becoming established. The Bear Lake and Reynolds Creek selections of mountain snowberry (*symphoricarpas oreophilus*) both showed excellent growth and earned the rating of Excellent in 1978.

A publication summarizing the data, including 1978 data, and findings at the three sites is in progress.

TABLE 2.a.6.--Ratings of Reynolds Creek Plantings - 1978.

			Area of Adaptation		
Symbol	Scientific Name	Source	Flats	Nancy Gulch	Reynolds Mtn.
Grasses					
AGCR x AGDE B1-68	*Agropyron cristatum x* *A. desertorum*	Logan AR	2[1/]	2	3
AGCRF B9-70 (B10-65)	*A. cristatum fairway*	Colorado (Commercial)			3
AGDA x	*A. dasystachyum x*	Logan AR		0	3
AGCA B1-69	*A. caespitosum*				
AGDE B1-68	*A. desertorum*	Montana		2	3
AGDE B2-68	*A. desertorum*	Montana (Nordan)	3	3	3
AGEL B5-69	*A. elongatum*	Commercial	3	3	3
AGIN B4-68	*A. intermedium*	Wyoming (Oahe)		3	3
AGIN B5-68	*A. intermedium*	Washington (Greenar)		0	2
AGIN B6-68	*A. intermedium*	Commercial (Amur)	3	0	3
AGIN B13-70	*A. intermedium*	Commercial (Tegmar)		3	3
AGJU B3-74	*A. junceum*	France PI276566			2
AGRE x AGDE	*A. repens x* *A. desertorum*				3
AGRI B1-69	*A. riparium*	Commercial (Sodar)	3	2	2
AGSI B1-68	*A. sibiricum*	Idaho	3	3	2
AGSM B1-68	*A. smithii*		3	1	1
AGTR B5-68	*A. trachycaulum*	Montana (Commercial)			0
AGTR2 B2-68	*A. trichophorum*	Colorado (Luna)	3	3	1
AGTR2 B3-68	*A. trichophorum*	Idaho (Topar)	3	2	2
ALPR B4-69	*Alopechrus pratensis*	Commercial			3
BRBI B1-66	*Bromus biebersteinii*				3
BRCA B4-74	*B. carinatus*	Leadville, Colorado			3
BRIN B6-74	*B. inermis*	U.S.S.R. PI315374			3
BRIN B7-74	*B. inermis*	U.S.S.R. PI315378			3
BRIN B13-70	*B. inermis*		2		
BRIN B19-74	*B. inermis*	GBRS (Northern)		3	3
BRIN B22-67	*B. inermis*	Commerical (Manchar)			3

[1/]Numeric ratings are: 0, Failed after showing acceptable rating in 1976; 1, Fair; 2, Good; and 3, Excellent.

TABLE 2.a.6, continued.--Ratings of Reynolds Creek Plantings - 1978

			Area of Adaptation		
Symbol	Scientific Name	Source	Flats	Nancy Gulch	Reynolds Mtn.
BRIN B9-69	*B. inermis*	Commercial (Lincoln)			3
BRMA B6-69	*B. marginatus*	Pullman SCS (Bromar)			2
BRTO B6-66	*B. tomentellus*	SCS			2
CAEP B2-68	*Calamagrostis epigeios*	Commercial			3
DAGL B16-68	*Dactylis glomerata*	Yugoslavia PI251112		3	2
DAGL B17-65	*D. glomerata*	Ephraim dry land form	2	2	2
DAGL B24-65	*D. glomerata*	Yugoslavia PI251112		1	
DAGLH B2-74	*D. glomerata*	Australia PI209888			1
ELCI B8-72	*Elymus cinereus*	East Boise			2
ELJU B9-61	*Elymus junceus*	Tetonia, Idaho	1	2	
FEAR3 B3-68	*Festuca arundinacea*	Commercial (Fawn)			2
FEOVD B3-70	*Festuca ovina duriuscula*	Idaho (Doran)		2	3
FEOVSU B3-66	*F. ovina*	PI229450		3	3
PHPR B7-74	*Phleum pratense*	Missouri		2	3
POCO B4-69	*Poa compressa*	Northrup King			3
POPR B12-69	*P. pratensis*	Commercial		3	3
SEMO B5-62	*Secale montanum*	Pullman SCS		2	0
STVI B2-68	*Stipa viridula*	Montana (Commercial)			1
Forbs					
ACMIL B8-74	*Achillea millefolium lanulosa*	Reynolds Creek			3
BAMA B1-69	*Balsamorhiza macrophylla*	Cache Co., Utah			3
BASA B9-72	*B. sagittata*	Coeur d'Alene, Idaho			3
COVA B3-67	*Coronilla varia*	Nebraska (Pingifit)			3
COVA B4-67	*C. varia*	Commercial (Emerald)			3
ERUM B5-74	*Eriogonum umbellatum*	Grimes Creek, Idaho			2
HEBOU B6-69	*Hedysarum boreale utahensis*	R. Stewart			0
LILE B3-70	*Linum lewisii*	Snow College Farm	3	3	0

TABLE 2.a.6, continued.--Ratings of Reynolds Creek Plantings - 1978

			Area of Adaptation		
Symbol	Scientific Name	Source	Flats	Nancy Gulch	Reynolds Mtn.
LOCO[3] B5-68	*Lotus corniculatus*	Vermont (Broadleaf)			2
LOCO[3] B6-68	*Lotus corniculatus*	California (Narrowleaf)			1
LOCO[3] B7-68	*L. corniculatus*	Canada (Empire)			3
LOCO[3] B8-59	*L. corniculatus*	Iowa			3
MEOF B1-69	*Melilotus officinalis*	Montana		2	2
MESA B9-69	*Medicago sativa*	Idaho (Rhizoma)		2	2
MESA B10-69	*M. sativa*	Idaho (Nomad)		2	2
MESA B11-69	*M. sativa*	Idaho (Ladak)		2	2
MESA B13-70	*M. sativa*	Commercial (Rambler)		2	3
MESA B32-66	*M. sativa*	S. Dakota		2	2
MESA B61-74	*M. sativa*	Commercial			2
ONVI B10-69	*Onobrychis viciaefolia*	Montana (Eski)			2
SAMI B10-70	*Sanguisorba minor*	NK Oregon Commercial		2	1
SOGI B1-74	*Solidago gigantea*	Reynolds Creek			3
VIVI B1-60	*Vicia villosa*	Major's Flat, Utah			0
<u>Shrubs</u>					
ACGL[2] B3-74	*Acer glabrum douglasii*	Reynolds Creek			0
AMAL B10-74	*Amelanchier alnifolia*	Bonneville Co., Idaho			3
AMUT B1-67	*A. utahensis*	Henryville, Utah			0
ARTRV B3-74	*Artemisia tridentata vaseyana*	Reynolds Creek			2
ATCO B3-74	*Atriplex confertifolia*		1		
CEVE B9-74	*Ceanothus velutinous*	Reynolds Creek			2
CELA B5-74	*Ceratoides lanata*	Reynolds Creek	2		
CHNA B17-74	*Chrysothamnus nauseosus*	Reynolds Creek		1	
COMES B3-70	*Cowania mexicana stansburiana*	American Fork, Utah		1	0
EPNE B3-71	*Ephedra nevadensis*	Pine Valley, Utah	1	1	
PREM B4-74	*Prunus emarginata*	Reynolds Creek			0

TABLE 2.a.6, continued.--Ratings of Reynolds Creek Plantings - 1978.

			Area of Adaptation		
Symbol	Scientific Name	Source	Flats	Nancy Gulch	Reynolds Mtn.
PUTR B1-69	*Purshia tridentata*	Moffet Co., Colorado		2	2
PUTR B2-69	*P. tridentata*	Fremont Co., Idaho			2
PUTR B5-72	*P. tridentata*	Boise		0	3
PUTR B21-63	*P. tridentata*	Eureka, Utah			2
PUTR B24-67	*P. tridentata*	Mono Lake, California			2
PUTR B36-73	*P. tridentata*	Washoe Co., Nevada		0	
ROWO B17-74	*Rosa woodsii*	Reynolds Creek			3
SYOR B1-69	*Symphoricarpos oreophilus*	Bear Lake, Utah			3
SYOR B13-74	*S. oreophilus*	Reynolds Creek			3

b. Boise Front

(Boise Front Watershed study sites are located on Introduction, Figure 2.)

Cattle use: Ideal spring moisture and temperatures provided an abundance of grass on the Boise Front, and grazing began on April 1, (Table 2.b.1). Grazing animals had not completely utilized the Picket Pin segment of high pasture 1 during previous years; therefore, it was decided that for the 1978 grazing season, the Picket Pin segment would be used beginning April 1. Early use permitted grazing the wheatgrasses at a growth stage when they were more palatable. The 1978 use dates for each of the pastures are shown in Table 2.b.2. A summary of cattle grazing by the two permittees using the Boise Front, as provided by the Idaho Fish and Game, follows:

The two ranchers holding grazing permits for the Boise Front are arbitrarily referred to as permittee No. 1 and permittee No. 2. On April 1, 1978, permittee No. 1 turned out 161 cows, 109 calves, and 2 bulls, while permittee No. 2 turned out 43 cows and 3 bulls in the Picket Pin segment of high pasture 1. The cattle spread over the area and utilized the forage very well.

On May 18, each of the permittees moved their cattle to low pasture 2. Bitterbrush hedging was accomplished in this pasture.

Between July 17 and July 26, permittee No. 1 moved the cattle from low pasture 2 to high pasture 2. However, some of the cows kept returning to low pasture 2 and had to be moved back to high pasture 2 several times.

From September 7 to September 14, permittee No. 1 moved the cows from high pasture 2 to the remaining part of high pasture 1. At this time, it appeared that some of permittee No. 2's cows had returned to his home range.

The gates between high pasture 1 and low pasture 1 were opened September 29 to let the cows start moving down.

TABLE 2.b.1--Grazing schedule and type of management for Boise Front pastures.

Year	Pasture			
	High or Low, 1	High or Low, 2	High or Low, 3	High or Low, 4
1978	C Early Rest (until seed ripe) (Graze Picket Pin 4/1-5/8)	A Graze Season Long	D Rest Season Long (seedling	B Rest Season Long (for plant vigor)
1979	D Rest Season Long (seedling establishment)	B Rest Season Long	A Graze Season Long	C Early Rest (until seed ripe)
1980	A Graze Season Long	C Early Rest (until seed ripe)	B Rest Season Long (for plant vigor)	D Rest Season Long (seedling establishment)
1981 (1977)	B Rest Season Long (for plant vigor)	D Rest Season Long (seedling establishment)	C Early Rest (until seed ripe)	A Graze Season Long

TABLE 2.b.2.--Dates cattle grazed Boise Front pastures during 1978.

Pasture	Cattle Grazing Dates	Time for Cattle to move between pastures [1]
High 1 (Picket Pin only)	April 1-May 17	
Low 2	May 18-July 16	May 18
High 2	July 17-Sept. 6	July 17-July 6[2]
High 1 (less Picket Pin)	Sept. 7-Sept. 28	Sept. 7-Sept. 14
Low 1	Sept. 29-Oct. 31	Sept. 29-Oct. 31

[1] Dates indicate opening and closing of gates.

[2] 127-head remained in low pasture 2 until July 26.

TABLE 2.b.3.--Rate of gain of randomly selected cattle during 1978.

	AVERAGE		RANGE	
	Rate of Gain	Pounds Gained	Rate of Gain	Pounds Gained
	Pounds Per Day		Pounds Per Day	
Calves	.95	206.48	.55-1.68	120-365
Heifers	.94	203.57	.67-1.68	145-365
Steers	.98	211.84	.55-1.66	120-360

On October 29, permittee No. 1 started rounding up the cows and moved them to the White Ranch to be worked. About 20 head were still missing by October 31, eventually most were located and taken home. Very few of permittee No 2's cattle showed up in the final round-up, indicating that they had returned home on their own. A random sample of calves were weighed on October 31, with the results shown in Table 2.b.3.

Sheep use: The sheep using the Boise Front consisted of one band that grazed for 30 days in the spring and again for 30 days in the fall. The sheep came into the project area around May 9, 1978, and were loaded out around Memorial Day. They went through low pasture 1, high pasture 1, high pasture 2, and high pasture 3.

A second band spent 3 days on the project prior to being loaded out with the first band about Memorial Day.

In the fall, the sheep came into the project on October 26 in high pasture 4. They then moved through high pasture 3, low pasture 3, low pasture 4, low pasture 2, and low pasture 1. The operator felt that because of lack of fall rain, he would not be able to hold his sheep in the lower pastures for more than 10 days, and was allowed to spend more time in high pasture 3 and low pasture 4. The sheep left the project around December 1, 1978.

Deer use: The Boise Front rotation grazing pastures serve as a winter deer range. Bitterbrush is the main browse plant. Utilization information was collected during the spring of 1978, the results of which are listed in Table 2.b.4. Of the available leaders, 46 percent or more showed use on all transects. Twig length utilization was the least in low pasture 1. This could be attributed to lower deer concentrations. Transect No. 23 in low pasture 2 is located in an area where greater deer concentrations occur and showed heavier utilization than Transect No. 3-3C. Transect No. 17 in low pasture 3, also in an area of higher deer concentration, showed more utilization than No. 10 in the same pasture.

TABLE 2.b.4.--Bitterbrush utilization on the Boise Front pastures during the summer of 1977 and the winter of 1977-1978.

Pasture	Transect No.	Percent of Available Twigs Showing Hits	Percent of Total Utilization[1/]
Low 1	20	60.4	15.4
Low 1	3-3A	46.7	8.1
Low 2	3-3C	60.0	18.3
Low 2	23	81.0	24.8
Low 3	17	74.5	20.6
Low 3	10	68.4	11.7
High 3	3-3B	84.3	28.3
Low 4	34	76.1	28.8

[1/] Use of annual growth equals percent of twigs taken times percent of available leaders used.

The high pasture 3, Transect No. 3-3B, consists of an older stand of bitterbrush, making measurement difficult. Grasshopper infestation during the summer of 1977 also hindered bitterbrush development. The measurements in high pasture 3 do not differentiate between deer and cattle use. Heavier deer concentrations were observed in this area, and a major portion of the twigs utilized would certainly be from deer.

The low pasture 4, Transect No. 34, also does not differentiate between deer and cattle use, but cattle were in this pasture for a shorter period of time in 1977 because some springs were dry. Deer concentrations were also heavier in this pasture, reflecting a higher amount of utilization by deer.

Measurement of bitterbrush utilization will continue, as this data provides important information regarding deer use of browse species on the Boise Front. Since the method recently described by Ferguson and Marsden[1/] uses a larger sample and should provide greater accuracy, current sampling procedures are being reviewed and may be revised.

Species and cover data: Frequency count data and cover information were collected at the rotation grazing study sites on low pastures 1, 2, and 3. The presence of any plant species occurring within an 18-inch^2 quadrant was identified. One hundred quadrant placements were used for each of the exclosure and rotation grazed treatments at each site. The frequency data were expressed as mean frequency percentage and are shown in Table 2.b.5.

The 1978 season was the second year for frequency sampling. Livestock use on the study sites in 1978 was similar to that of 1977, and there was no noticeable difference of species composition between treatments. The number of plant species increased greatly due to ideal growing conditions in the spring of 1978.

[1/] Ferguson, Robert B. and Michael A. Marsden. 1977. Estimating over-winter bitterbrush utilization from twig diameter-length-weight relations. Journal of Range Management 30:(3)231-236.

TABLE 2.b.5--Frequency percentage of plant species within exclosure and on adjacent rotation grazing pastures.

	Pasture							
	Low 1		Low 2 Maynard Gulch 1/		Low 2 (Pond Spring) 1/		Low 3	
	Exclosure	Rotation Grazed	Exclosure	Rotation Grazed	Exclosure	Rotation	Exclosure	Rotation
Agropyron intermedium							1	
Agropyron spicatum		1		4				
Aristida longiseta	5				1		15	1
Bromus tectorum	100	100	95	81	100	99	68	53
Festuca arida	82	49					36	89
Festuca megalura	39	26	65	29	94	91	1	
Poa sandbergii	83	83	98	96			81	95
Sitanion hystrix	81	91	95	82	16	13	79	95
Taeniatherum caput-medusae					100	100	9	2
Achillea millefolium lanulosa		1						2
Agoseris species	1	1						5
Amsinkia retrorsa	61	69	71	56	9	3	3	1
Antennaria dimorpha	2			1			9	5
Astragallus species	12	18	11	18			5	1
Balsamorhiza sagittata		3	54	1				
Blepharipappus scaber	73	59		8		1	38	42
Calohortus macrocarpus	1		1	2	4		3	1
Cirsium canovirens	6	1	1	2				
Crepis occidentalis	43	23	3	4	11	13	15	3
Cryptantha species		11	44	46			3	
Epilobium paniculatum	8	77	77	75		5	32	64
Erodium circutarium	69	83	54	46	100	100	53	33
Eriogonum vimineum	40	44	17	6				
Heliamthus species	18	13	6	2	42	74	49	16
Holosteum umbellatum	99	49					82	95
Lactuca species				15				
Lagophylla ramosissima							9	20
Lactuca serriola	68	74	43	49	90	86	4	8
Lepidium species	97	71	100	95	48	24	70	69
Lomatium nudicaule				2				
Lomatum triternatum platycarpum			3	5				
Lupin species				3				
Myosotis species							34	44
Phlox species	10	8	15	41				1
Plectritis macrocera				2				12
Polygonum majus								
Thysanocarpus curvipes			10	4				
Tragopogon dubius							29	55
Forb	1	3						
Artemisia tridentata							1	
Chrysothamnus nauseosus albicaulis							3	

1/Grazed 1978.

Overstory vegetation measurements were collected again in 1978. Table 2.b.6 shows a comparison of vegetative hits in 1977 and 1978. Little difference would be expected between the exclosures and rotation grazed treatments; however, the differences between 1977 and 1978 reflect the increase in overstory vegetative cover in 1978 due to ideal growing conditions. There was a slight decrease in vegetative cover on the grazed treatment at the low pasture 3 site in 1978.

Table 2.b.7 shows the 1977 and 1978 basal cover. At the low pasture 1 site, vegetal cover decreased in both the exclosure and the pasture. At the low pasture 2 site (Maynard Gulch), the vegetal cover decreased in the exclosure and increased in the pasture. Vegetation cover at the low pasture 2 site (Pond Spring) increased in 1978, while there was very little change at the low pasture 3 site. The ideal spring moisture did not appear to increase basal cover appreciably, except at the low pasture 2 site (Pond Spring) where the basal cover is more dense. Surface litter decreased at all sites. Rock remained the same, except on the exclosure in low pasture 1. Ground cover remained high at all sites, except at the low pasture 2 site (Maynard Gulch).

TABLE 2.b.6.--Percent overstory for different cover components at four rotation pasture sites in 1977 and 1978.

	Pasture							
	Low 1		Low 2 (Maynard Gulch)		Low 2 (Pond Spring)		Low 3	
	1977	1978	1977	1978	1977	1978	1977	1978
VEGETATION TOTAL								
Exclosure	26	48.1	41	43.2	47	58.9	37	43.4
Rotation Grazed	33	58.2	33	40.7	58	75.7	52	45.8
LITTER								
Exclosure	24	21.4	19	5.8	48	33.6	27	14.1
Rotation Grazed	14	2.7	18	4.8	36	20.6	17	18.3
ROCK								
Exclosure	11	13.6	2	3.4	0	1.2	5	5.9
Rotation Grazed	15	11.3	3	2.2	2	1.0	6	4.3
BARE GROUND								
Exclosure	39	16.9	38	47.6	5	6.3	31	36.6
Rotation Grazed	38	27.8	46	52.3	4	2.7	25	31.6

TABLE 2.b.7--Percent basal cover for different components at four rotation pasture sites in 1977 and 1978.

	Pasture							
	Low 1		Low 2 (Maynard Gulch)		Low 2 (Pond Spring)		Low 3	
	1977	1978	1977	1978	1977	1978	1977	1978
VEGETATION TOTAL								
Exclosure	17	6.5	32	23.4	15	21.9	18	15.4
Rotation Grazed	28	19.3	20	27.4	8	28.5	9	11.9
LITTER								
Exclosure	32	28.0	23	12.3	78	64.6	36	27.8
Rotation Grazed	19	7.8	24	9.6	85	64.8	59	40.3
ROCK								
Exclosure	11	33.3	3	4.2	2	1.9	5	8.0
Rotation Grazed	15	17.1	4	3.7	2	1.0	6	5.5
BARE GROUND								
Exclosure	40	32.2	42	60.1	5	11.6	41	48.8
Rotation Grazed	38	55.8	52	59.3	5	5.7	26	42.3

3. RUNOFF

Personnel Involved

C. W. Johnson, Research Hydraulic Engineer	Plan programs and procedures; design and construct facilities for runoff studies; perform analyses and summarize results.
D. L. Brakensiek, Research Hydraulic Engineer	Streamflow and infiltration modeling.
C. L. Hanson, Agricultural Engineer	Test various components in runoff models most applicable to rangelands.
R. L. Engleman, Mathematician	Perform data compilation and assist in analyses.
J. P. Smith, R. P. Morris, and V. M. Aaron, Hydrologic Technicians	Data collection, compilation, and analyses.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and radio telemetry systems.
D. C. Robertson, Hydrologic Technician	Snowmelt runoff.

a. Reynold Creek

(Reynolds Creek site locations are shown on Introduction, Figure 1.)

MICROWATERSHEDS

Flats: The only storm that produced runoff from this 2.24-acre watershed occurred April 25-27, 1978. Daily rainfall and runoff amounts for this storm are listed in Table 3.a.1. Comparisons can be made with all watersheds. The maximum rainfall intensity during the storm was 1.49 in/hr on April 25, and did not produce runoff. Runoff did not begin until about 1.2 inches of rainfall had thoroughly wet the surface soil. Runoff lasted for about an hour and totaled only 0.005 inch, while the rainfall intensity was about 0.4 in/hr. Storm runoff was much less than from larger watersheds. Total water year precipitation at this station was 12.137 inches, with 3.189 inches in April. The 15-year average precipitation at this station is 10 inches.

Nancy Gulch: The April 25-27 storm produced runoff from the 3.1-acre Nancy Watershed on April 26 and 27, although the total amount was only 0.002 inch, Table 3.a.1. The maximum rainfall intensity was 0.9 in/hr on April 25, and did not produce runoff. However, intensities of 0.5 in/hr on April 26 and 0.18 in/hr on April 27 produced measurable runoff. Total storm rainfall was 2.3 inches, compared with 2.1 inches at the Flats, but runoff was only about half as much. Water year precipitation was 14.175 inches, compared with a 15-year mean of 10.2 inches.

Storm runoff from the Flats and Nancy Microwatersheds was much less than from all larger watersheds, which illustrates the difficulties of extrapolating runoff records from very small watersheds to much larger watersheds.

SOURCE WATERSHEDS

Lower Sheep: Runoff from this 33-acre watershed in the 1978 water year was 0.14 inch, about half the 12-year mean at this station, Table 3.a.2. Precipitation was 15.13 inches, about 8 percent above the 15-year mean. The peak runoff rate was only 0.1 ft^3/sec, compared with an average yearly peak of 0.5 ft^3/sec. The runoff peak was caused by rainfall on April 27. About 80 percent of the yearly runoff was from intermittent snowmelt in January, February, and March; and 20 percent was from rainfall in April.

TABLE 3.a.1.--Daily rainfall and runoff for storm of April 25-27, 1978, Reynolds Creek Watershed

Watershed	April 25		April 26		April 27		Storm Total	
	Rainfall	Storm Runoff	Rainfall	Storm Runoff	Rainfall	Storm Runoff	Rainfall	Storm Runoff
	Inches							
Flats	0.601	0	1.282	0.005	0.225	0	2.108	0.005
Nancy	0.571	0	1.354	0.001	0.375	0.001	2.300	0.002
Lower Sheep	0.306	0	1.286	0.010	0.337	0.017	1.929	0.027
Salmon Creek	0.287	0	1.321	0.091	0.932	0.162	2.540	0.253
Macks Creek	0.268	0	1.102	0.089	0.483	0.122	1.853	0.211
Tollgate	0.356	0.025	1.136	0.173	0.156	0.134	1.648	0.332
Dobson Creek	0.331	0.015	1.130	0.170	0.419	0.125	1.880	0.310
Reynolds Mountain West	0.311	0.151	1.527	0.278	0.547	0.153	2.385	0.582
Reynolds Mountain East	0.311	0.133	1.527	0.309	0.547	0.164	2.385	0.606
Reynolds Outlet	0.239	0.001	1.074	0.098	0.317	0.098	1.630	0.197

Table 3.a.2.--Water year precipitation, runoff, and peak streamflow, source watersheds, Reynolds Creek Experimental Watershed.

	Lower Sheep Watershed				Reynolds Mountain East Watershed				Reynolds Mountain West Watershed			
Water Year	Precipi-tation	Runoff	Peak Streamflow	Date of Peak	Precipi-tation	Runoff	Peak Streamflow	Date of Peak	Precipi-tation	Runoff	Peak Streamflow	Date of Peak
	inches	*inches*	*ft^3/sec*		*inches*	*inches*	*ft^3/sec*		*inches*	*inches*	*ft^3/sec*	
1963	16.98	--[1/]	--	--	37.82	11.11	4.16	Apr. 29	--[2/]	--[3/]	--	--
1964	13.55	--	--	--	40.89	21.02	3.60	May 16	--	--	--	--
1965	20.86	--	--	--	66.10	34.87	10.70	Dec. 23	--	25.00	9.29	Dec. 23
1966	6.81	--	--	--	28.36	9.86	1.43	May 5	--	7.39	1.87	Apr. 8
1967	18.73	0.34	1.41	Jan. 21	50.45	21.01	5.44	May 22	--	17.18	5.10	May 22
1968	11.30	0.02	0.08	Feb. 18	31.97	6.72	1.48	Aug. 10	--	6.31	1.97	Feb. 23
1969	14.12	0.52	0.49	Jan. 20	37.45	22.43	3.88	May 12	37.37	17.26	4.20	May 10
1970	14.24	0.02	0.05	Jan. 27	39.60	20.06	5.89	May 17	37.95	20.24	12.33	May 17
1971	17.68	0.31	0.20	Mar. 12	57.96	31.06	5.77	May 4	45.75	21.41	10.24	May 4
1972	13.82	0.91	2.08	Jan. 22	50.51	33.52	6.26	Jun. 6	45.98	29.56	6.31	May 14
1973	12.20	0.01	0.02	Apr. 17	31.01	13.24	3.31	May 8	28.40	10.02	5.35	Apr. 27
1974	10.28	0.26	0.38	Mar. 15	45.54	26.64	4.33	May 7	38.67	19.77	5.61	May 7
1975	14.89	0.73	0.90	Feb. 13	51.57	27.93	9.27	Jun. 2	42.83	21.24	14.28	Jun. 2
1976	14.46	0.55	0.31	Mar. 17	42.51	22.35	4.59	May 13	--	16.38	4.09	May 2
1977	8.27	0	0	--	21.11	3.44	0.93	Apr. 16	--	2.31	0.72	Apr. 16
1978	15.13	0.14	0.09	Apr. 27	43.82	23.12	4.50	May 14	--	17.07	3.52	May 14
MEAN	13.96	0.31	0.50	--	42.29	20.52	4.73	--	--	16.51	6.06	--

1/ Runoff station record began in 1966.

2/ Precipitation record began in 1968 and terminated in 1975.

3/ Runoff station record began in 1964.

Reynolds Mountain East: Runoff from this 100-acre watershed, above 6600 feet elevation, was 23.1 inches--13 percent greater than the 15-year mean, Table 3.a.2. The peak runoff rate was 4.5 ft^3/sec on May 14, from snowmelt, slightly less than the 16-year mean of 4.7 ft^3/sec. Water year precipitation was 43.82 inches, about 4 percent greater than the 16-year mean. Summer streamflow was lower than normal, because May-September precipitation was only about 70 percent of normal.

Reynolds Mountain West: Runoff from this 126-acre watershed was 17.07 inches--3 percent greater than the 14-year mean, Table 3.a.2. The peak runoff rate was 3.52 ft^3/sec on May 14, much less than the mean of record. Precipitation was measured on the adjoining Reynolds Mountain East Watershed.

TRIBUTARY WATERSHEDS

Salmon Creek: Runoff from this 8900-acre watershed was 3.41 inches in 1978, about 8 percent greater than the 14-year mean, Table 3.a.3. The peak runoff rate was 102 ft^3/sec on April 27, about half the mean value. Water year precipitation was 23.42 inches, 14 percent greater than the 16-year mean. Precipitation on April 27 was 0.93 inch, the greatest of any station on that date, which caused higher peak runoff than from the adjoining Macks Creek Watershed, Table 3.a.1. Thus, we see the importance of on-site precipitation measurements in developing hydrologic relationships.

Macks Creek: Runoff from this 7846-acre watershed was 3.01 inches, about 20 percent greater than the 13-year mean, Table 3.a.3. The peak runoff rate was 86 ft^3/sec on April 26, compared with a mean of 117 ft^3/sec. Water year precipitation was 24.61 inches, 23 percent greater than the 10-year mean.

Dobson Creek: Runoff from this 3482-acre watershed was 13.00 inches, about 10 percent greater than the 6-year mean, Table 3.a.3. The peak runoff rate was 66 ft^3/sec on April 26, slightly greater than the mean of record. Precipitation was 36.3 inches, about equal to the 16-year mean. Records at this station are too short for meaningful comparison.

TABLE 3.a.3.--Water year precipitation runoff, and peak streamflow, Tributary Watersheds, Reynolds Creek Experimental Watershed.

	Salmon Creek			Macks Creek			Dobson Creek		
Water Year	Precipi-tation	Runoff	Peak Streamflow	Precipi-tation	Runoff	Peak Streamflow	Precipi-tation	Runoff	Peak Streamflow
	inches	*inches*	ft^3/sec	*inches*	*inches*	ft^3/sec	*inches*	*inches*	ft^3/sec
1963	22.63	--	--	--	--	--	36.12	--	--
1964	19.90	--	--	--	--	--	32.48	--	--
1965	33.51	9.65	1523	--	--	--	40.89	--	--
1966	10.27	1.05	10	--	0.61	12	23.78	--	--
1967	22.77	2.24	85	--	1.54	90	39.56	--	--
1968	14.73	.77	34	--	0.49	44	32.54	--	--
1969	19.36	3.14	209	19.90	2.93	307	40.61	--	--
1970	24.96	3.07	210	19.29	1.92	241	41.67	--	--
1971	24.35	3.61	132	23.65	3.79	281	52.68	--	--
1972	22.74	5.50	201	23.43	4.84	138	42.29	--	--
1973	17.35	2.14	55	15.93	1.76	54	28.93	7.62	49
1974	16.80	3.31	53	15.54	3.72	71	38.94	17.42	82
1975	20.43	3.54	92	22.68	4.79	142	41.85	16.78	65
1976	22.81	2.38	19	21.02	2.67	33	38.37	12.97	43
1977	12.53	0.62	103	14.67	0.43	19	20.62	2.86	9
1978	23.42	3.41	102	24.61	3.01	86	36.30	13.00	66
MEAN	20.54	3.17	202	20.07	2.50	117	36.73	11.78	52

MAIN STEM WATERSHEDS

Reynolds Creek Outlet: Runoff from this 57,700-acre, 90.16 mi^2 watershed was 3.29 inches, 8 percent greater than the 16-year mean, Table 3.a.4. The peak runoff rate was 589 ft^3/sec on April 26--24 percent less than the yearly mean peak. Precipitation and runoff from contributing watersheds for the April 25-27 storm are summarized in Table 3.a.1 to show the range in daily storm values. Precipitation in 1978 was about 5 percent greater than the mean.

Reynolds Creek Tollgate: Runoff from this 13,453-acre, 21.02 mi^2 watershed was 11.32 inches, about 20 percent greater than the 13-year mean, Table 3.a.4. The peak runoff rate was 230 ft^3/sec on April 26--16 percent greater than the yearly mean of record. Precipitation was 28.98 inches, only one percent greater than the mean. The monthly runoff distributions in 1978, Table 3.a.5, at Reynolds Creek stations show that January runoff was less than normal, and that March to May runoff was greater than normal. The 1 to 5 percent greater precipitation produced 8 to 20 percent greater runoff in 1978, probably because of the cooler than normal temperatures during the snowmelt season.

WATERSHED MODELS

Runoff: The following is a summary of procedures being used by various State and Federal agencies to estimate runoff curve numbers (CN) for rangeland, (Stewart et al. 1976; USDA, Soil Conservation Service, 1972). USDA, Soil Conservation Service (1972) and USDI, Bureau of Land Management (1969) have graphs to use for estimating curve numbers for Pinyon-Juniper and sagebrush cover classes. USDI, Bureau of Land Management (1969) also have a graph for grassland. These graphs are based on the hydrologic soil groups and percentage of cover. The percentage of cover classifies the cover in poor, fair, and good hydrologic condition. Two procedures for determining the hydrologic cover condition of rangeland are given in Chapter 8 of the SCS National Engineering Handbook, Section 4, Hydrology (USDA, Soil Conservation Service, 1972). The Soil Conservation Service has also developed "Hydrology Technical Note, PO-7", which is a photographic catalog illustrating various range sites and hydrologic conditions (USDA, Soil Conservation Service, 1973a).

The Soil Conservation Service in Arizona and New Mexico has developed a figure representing curve numbers for their hydrologic conditions. Their figure was based on Figures 9.5 and 9.6 in the SCS National Engineering Handbook, Section 4, and expresses the runoff curve numbers as a function of cover density and hydrologic soil type for various vegetation types (Simanton, Renard, and Sutter, 1973; USDA, Soil Conservation Service, 1973b). The Soil Conservation Service in Arizona has also

TABLE 3.a.4.--Water year precipitation, runoff, and peak streamflow for main stem watersheds.

	Reynolds Creek Outlet				Reynolds Creek at Tollgate			
Water Year	Precipi- tation[1]	Runoff	Peak Streamflow	Date of Peak	Precipi- tation[2]	Runoff	Peak Streamflow	Date of Peak
	inches	*inches*	ft^3/sec		*inches*	*inches*	ft^3/sec	
1963	25.03	1.85	2331	Jan. 31	31.07	--	--	--
1964	15.25	2.45	188	Jan. 25	24.25	--	--	--
1965	26.83	7.05	3850	Dec. 23	38.93	--	--	--
1966	9.05	0.76	59	Apr. 1	13.79	3.55	59	Apr. 1
1967	19.68	2.19	265	Jun. 7	28.10	9.09	288	Jun. 7
1968	14.20	0.61	327	Feb. 21	21.51	3.08	186	Feb. 21
1969	16.85	3.60	900	Jan. 21	29.11	11.47	405	Jan. 21
1970	20.13	2.70	729	Jan. 27	31.35	9.64	240	Jan. 27
1971	24.96	4.78	540	Jan. 18	41.89	14.98	193	May 6
1972	22.13	6.07	678	Mar. 2	38.12	16.45	271	Mar. 2
1973	16.19	1.85	166	Apr. 17	25.18	6.00	147	Apr. 17
1974	17.14	4.37	291	Mar. 29	29.53	12.75	195	Mar. 29
1975	19.57	4.12	281	Mar. 25	31.18	13.31	231	Jun. 2
1976	20.34	2.84	140	Apr. 5	29.90	10.05	130	May 10
1977	11.41	0.35	1119	Jun. 11	15.49	1.51	17	Apr. 8
1978	19.64	3.29	589	Apr. 26	28.98	11.32	230	Apr. 26
MEAN	18.65	3.06	778	--	28.65	9.48	199	--

[1]Rain gage No. 116X91.

[2]Rain gage No. 155X07.

TABLE 3.a.5.--Water year runoff in 1978, and the mean of record by months.

Month	Reynolds Creek Outlet Runoff		Reynolds Creek Tollgate Runoff	
	1978	1963-1978	1978	1966-1978
	--------------------inches--------------------			
October	0.003	0.026	0.024	0.085
November	0.013	0.049	0.092	0.141
December	0.106	0.178	0.393	0.235
January	0.139	0.413	0.256	0.615
February	0.261	0.271	0.389	0.421
March	0.733	0.491	1.831	1.070
April	0.885	0.594	3.086	1.824
May	0.828	0.636	3.667	3.254
June	0.212	0.311	1.199	1.482
July	0.065	0.050	.263	.259
August	0.031	0.023	.056	.051
September	0.015	0.014	.063	.038
Total	3.291	3.056	11.319	9.475

developed a method of adjusting curve numbers for storm duration (Woodward, 1973; Malone, 1972).

The Soil Conservation Service in Wyoming developed a table of soil cover complex numbers derived from range sites and condition cover (USDA, Soil Conservation Service, 1978). Table 3.a.6, a listing of runoff curve numbers as they relate to range sites and condition of cover, was adopted from the Wyoming SCS table for use in the northern Great Plains. The values in the table were verified from SEA-AR watershed data in western South Dakota, southeastern Montana, and northeastern Wyoming, and represent antecedent moisture condition I. The range condition classes of fair; good and high-fair; and excellent in the Wyoming SCS table have been changed to poor, fair, and good in this table to coincide with Tables 8.1 and 8.2 of the USDA, Soil Conservation Service (1972).

REFERENCES FOR ESTIMATING RUNOFF CURVE NUMBERS FOR RANGELAND

Malone, James M. 1972. Hydrologic design manual for drainage areas under 25 square miles. (Preliminary draft) USDA-SCS, Phoenix, AZ.

Simanton, J. R., Renard, K. G., and Sutter, N. G. 1973. Procedures for identifying parameters affecting storm runoff volumes in a semiarid environment. USDA-ARS, ARS-W-1. 12 p.

Stewart, B. A., Woolhiser, D. A., Wischmeier, W. H., Caro, J. H., and Frere, M. H. 1976. Control of water pollution from cropland, Volume II-an overview. USDA-ARS, Report No. ARS-H-5-2. 187 p.

USDA, Soil Conservation Service. 1972. SCS National Engineering Handbook, Section 4, Hydrology.

USDA, Soil Conservation Service. 1973a. Photographic catalog of range sites and their hydrologic condition. USDA-SCS, Hydrology Technical Note, PO-7. 23 p.

USDA, Soil Conservation Service. 1973b. Peak rates of discharge for small watersheds. Engineering Field Manual for Conservation Practices, Chapter 2, Revised 10/73 for New Mexico.

USDA, Soil Conservation Service. 1978. Runoff and yield determination procedures. USDA-SCS Technical Note-Engineering 18, Page 16, Table 3. Casper, WY.

USDI, Bureau of Land Management. 1969. Bureau of Land Management, Manual 7313-Cover.

Woodward, Donald E. 1973. Runoff curve numbers for semiarid range and forest conditions. ASAE Paper 73-209, ASAE, St. Joseph, MI. 49085.

TABLE 3.a.6.--Runoff curve numbers for northern Great Plains derived from range sites and condition cover for antecedent moisture condition I

Range Site[1/]	Range Condition Class Poor	Fair	Good
Wetland	95	95	95
Very Shallow	95	90	85
Saline Sub-irrigated	90	90	85
Shale	90	85	80
Dense Clay	90	85	80
Alkali Clay	90	85	80
Saline Upland	90	85	80
Igneous	90	80	75
Shallow Clayey	85	80	75
Shallow Sandy	80	75	70
Shallow Loamy	80	75	70
Shallow Igneous	80	75	70
Steep Clayey	80	75	70
Clayey	80	75	65
Gravelly Loamy	80	75	65
Steep Loamy	80	75	65
Overflow	80	70	60
Loamy Overflow	80	70	60
Clayey Overflow	80	70	60
Coarse Upland	80	70	60
Limy Upland	80	70	60
Shallow Breaks	80	70	60
Stony	80	70	60
Steep Stony	80	70	60
Lowland	80	70	60
Saline Lowland	80	70	60
Loamy Lowland	80	65	55
Loamy	80	65	55
Sandy Lowland	75	60	50
Sandy	75	60	50
Gravelly	70	55	45
Sands	70	55	40
Choppy Sands	70	55	40

1/ The above listed sites and conditions are general and the curve number should be adjusted (interpolated) for each particular site, based upon a field investigation.

Infiltration: Interim Reports No. 7 and 8 reported progress on estimating the parameters of the Green and Ampt infiltration equation from sprinkling and ponding type infiltrometers. In this report, the Green and Ampt parameters are estimated from desorption (drainage) soil water content-capillary pressure (matric suction) data points (the desorption characteristic). The Green and Ampt equation is written as

$$f = K\left(1 + \frac{n\,\psi_f}{F}\right) \qquad (1)$$

where

f = Infiltration rate, cm/min

F = Infiltration amount, cm

K = Conductivity, cm/min

ψ_f = Capillary pressure at the wetting front, cm

n = Fillable porosity

L = Wetted depth = F/n, cm

The three parameters, K, ψ_f, and n are estimated from the desorption data as follows: The desorption characteristic data is fitted by the Brooks and Corey equation

$$S_e = (\psi_b/\psi)^{\lambda} \qquad (2)$$

where, S_e is effective saturation, i. e.,

$$S_e = \frac{\theta-\theta_r}{\theta_s-\theta_r}$$

θ = Soil water content, cm^3/cm^3

θ_r = Residual soil water content, cm^3/cm^3

θ_s = Soil water content at saturation, cm^3/cm^3

and

ψ_b = Bubbling pressure, cm

ψ = Capillary pressure at a given soil water content, cm

λ = Pore size distribution parameter

Fitting Equation 2 yields values for ψ_b, λ, θ_r. A number of sets of soil desorption data have been collected for soils on experimental watersheds in the United States, including the Reynolds Creek, Idaho, soil shown in Tables 3.a.7 and 3.a.8. These are published in the Bulletin ARS 41-144, "Moisture-Tension Data for Selected Soils on Experimental Watersheds". In Figure 3.a.1, Equation 2 is plotted as ℓn (S_e) and ℓn (ψ) for the Nannyton loam taken from this publication. Specific values of θ_r were assumed. The "best" value of θ_r is that one giving the highest correlation. In Figure 3.a.1, it is seen that $\theta_r = 0.27$ produced the best fit line and the highest correlation. The slope of the fitted line is λ, and the ψ intercept at $\ell n\ S_e = 0$, i. e., $S_e = 1$, gives ψ_b.

The Green and Ampt parameters ψ_f, n, and K are now estimated from the Brooks and Corey parameters by the following equations:

$$\psi_f = \left(\frac{3+2\lambda}{2+2\lambda}\right)\left(\frac{\psi_b}{2}\right), \quad \text{(cm)} \tag{3}$$

$$n = \phi_e - ASM \tag{4}$$

where, ϕ_e is the effective porosity

$$\phi_e = \phi - \theta_r$$

$$\phi = \left(1 - \frac{BD}{2.65}\right)$$

and BD = Bulk density

Also, ASM is the antecedent soil moisture content on a volume basis. Saturated conductivity, K_s, is estimated as

$$K_s = 270 \frac{\phi_e^2}{\psi_b^2} \left(\frac{\lambda^2}{(\lambda+1)(\lambda+2)} \right), \text{ (cm/sec)}$$

Since K_s is estimated for soil water desorption (drainage), it has been found that the Green and Ampt parameter K for infiltration should be taken as one-half of K_s, i. e.,

$$K = K_s/2$$

If generalized values of the Green and Ampt parameters for specific soil textural classes were available, the application of the infiltration equation to runoff estimation would be possible. A study published by Clapp and Hornberger[1/] provides the first means to develop such generalized estimates. These estimates of the Green and Ampt parameters from the above equations are given in Table 3.a.10 for a range of soil textural classes.

TABLE 3.a.7.--Nannyton loam*

Horizon	Depth	Description
A1	0 to 1 inch	Granular fine sandy loam
A2	1 to 7 inches	Fine sandy loam; weak to moderate platy breaking to weak very fine granular structure; many coarse to medium and few fine roots.
B2t	7 to 11 inches	Fine sandy clay loam; weak to moderate subangular blocky structure; plentiful coarse and medium roots, few fine roots.
B3t	11 to 15 inches	Light clay loam; weak subangular blocky breaking to moderate to strong granular structure.
C	15 to 21 inches	Massive fine sandy loam, gravelly; few fine roots.
C1ca	21 to 32 inches	Massive gravelly sandy loam.
C2ca	32 inches plus	Very fine loamy sand; massive.

*Correlated as Nannyton loam (1967)

1/Water Resources Research, Vol. 14, No. 4, August 1978.

Location: Reynolds Creek Watershed; N of main road
Vegetation and land use: Range; shadscale
Topography: Level
Drainage: Good
Parent Material: Basalt-granite mixture
Described and sampled by: T. A. Goettling and G. A. Schumaker

TABLE 3.a.8.--Soil water desorption data for Nannyton loam, Reynolds Creek Watershed, Boise, Idaho

WEIGHT PERCENT AND VOLUME PERCENT OF WATER RETAINED

	TENSIONS (BARS)							
DEPTH	.1	.3	.6	3.	15.	BD G/CC	TP PCT	K IN/HR
0	27.81	16.90	14.06	13.02	8.51	1.27[1*]	52.08	.06
	35.31	21.46	17.85	16.53	10.80	1.47	44.53	.10
	FRAGMENT	15.62		SIEVED	11.06	ROCK PERCENT	21.19	
1	25.00	18.88	14.72	14.36	10.12	1.41[1*]	46.79	0
	35.25	26.62	20.75	20.24	14.26	1.54	41.89	.04
	FRAGMENT	21.40		SIEVED	9.96	ROCK PERCENT	9.09	
7	32.70	25.97	24.16	23.77	20.25	1.22[1*]	53.96	.40
	39.89	31.68	29.47	28.99	24.70	1.36	48.68	.29
	FRAGMENT	26.39		SIEVED	22.16	ROCK PERCENT	28.32	
11	36.26	28.49	21.87	20.18	19.68	1.25[1*]	52.82[3*]	.54
	45.32	35.61	27.33	25.22	24.60	1.30	50.94	.58
	FRAGMENT	28.94		SIEVED	27.35	ROCK PERCENT	27.16	
15	36.77	30.51	26.38	23.85	22.90	1.20[3*]	54.72	
	44.12	36.61	31.65	28.62	27.48			
	FRAGMENT			SIEVED	30.10	ROCK PERCENT	36.36	
21	21.45	18.70	17.77	16.30	15.48	1.53[3*]	42.26	
	32.81	28.61	27.18	24.93	23.68			
	FRAGMENT			SIEVED	19.66	ROCK PERCENT	64.48	
					(29.51)			
32	31.36	21.70	15.38	14.15	12.09	1.18[1*]	55.47	.43
	37.00	25.60	18.14	16.69	14.26	1.25	52.83	1.39
	FRAGMENT	20.17		SIEVED	14.11	ROCK PERCENT	17.27	

*1 = FIST; 2 = CORE; 3 = LOOSE

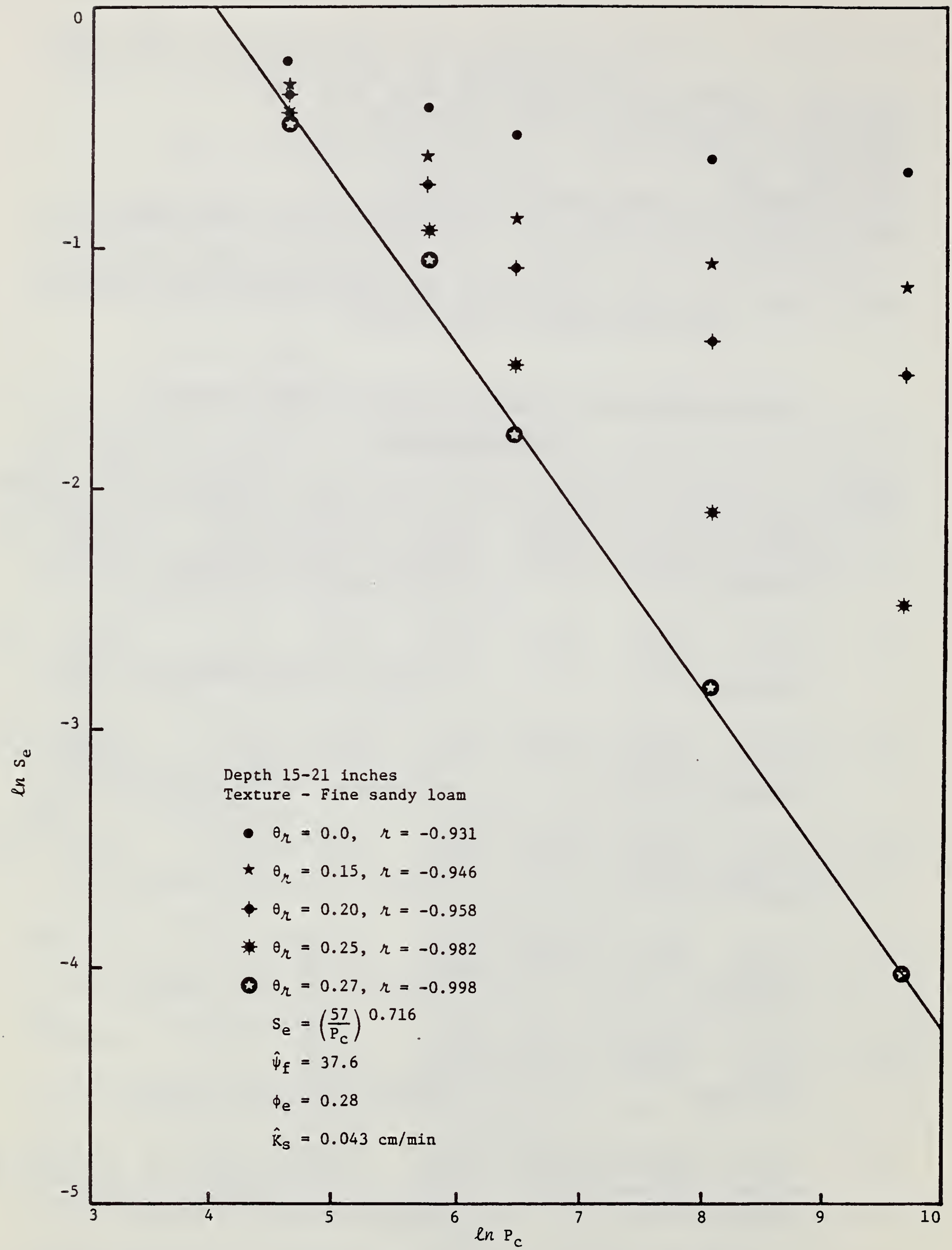

Figure 3.a.1.--Soil characteristic data for Nannyton loam fitted by the Brooks - Corey equation.

Note:

(1) First and third lines are percent of water retained by weight at each tension.

(2) Second line is percent by volume.

(3) First bulk density is obtained at 0.3 bar and second bulk density is for the oven dry sample.

(4) Total porosity calculation assumes the specific gravity for soils of 2.65.

TABLE 3.a.9.--Green and Ampt parameters estimated from the published Clapp and Hornberger data.

Soil Texture	ψ_f cm	K cm/min	ϕ_e
Sand	10.	0.19	.395
Loamy sand	7.	.32	.410
Sandy loam	18.	.05	.435
Silt loam	64.	.0048	.485
Loam	39.	.0095	.451
Sandy clay loam	25.	.013	.420
Silty clay loam	31.	.010	.477
Clay loam	55.	.0027	.476
Sandy clay	14.	.025	.426
Silty clay	44.	.0033	.492
Clay	36.	.0039	.482

The analysis by Clapp and Hornberger assumed that $\theta_r = 0$. As can be seen in Figure 3.a.1, this value may not give the best linear fit. A re-analysis of their basic data is underway, which will allow a non-zero value of θ_r. This should yield better estimates of the Brooks and Corey constants; and, in turn, this will provide improved Green and Ampt parameter values.

To illustrate the use of data, such as is in Table 3.a.9 for applying an infiltration equation to surface runoff estimation, a storm on Reynolds Creek is analyzed. In Table 3.a.10, the Green and Ampt parameters are presented for the soil texture classes appropriate to the Nannyton loam soil present on the Flats Microwatershed. The storm occurred on April 25 and 26 of 1978.

TABLE 3.a.10.--Green and Ampt infiltration equation parameters for Nannyton loam, Reynolds Creek Watershed.

Depth Inches	Textural Class	Green and Ampt Parameters from Table 3.a.9. ϕ_e	ψ_f cm	K cm/min
0-1	Sandy loam	.435	18.	.05
1-7	Sandy loam	.435	18.	.05
7-11	Sandy clay loam	.420	25.	.013
11-15	Clay loam	.476	55.	.0027
15-21	Sandy loam	.435	18.	.05
21-32	Sandy loam	.435	18.	.05
15" depth average values			29.7	0.006

From watershed soil moisture data, the volumetric antecedent soil moisture content was estimated as 0.26. The wetted depth for the storm period was approximately 15 inches; thus, the Green and Ampt parameters for this storm are as follows:

$$\psi_f = 29.7 \text{ cm (11.693 inches)}$$

$$K = .006 \text{ cm/min (0.142 in/hr)}$$

Fillable porosity, n, is calculated on a layer basis; for example, layer 1 and 2,

$$n = .435-.26 = 0.175$$

In Table 3.a.11, the storm rainfall and the observed runoff information are tabulated. The last two columns were calculated from the infiltration equation. Storm totals are shown at the bottom of the table.

TABLE 3.a.11.--Storm of April 25, 1978, on the Flats Microwatershed.

Date	Mil. Time	Rain Accum. In.	Rain Intensity In/Hr	Observed Runoff In.	Infil. Rate In/Hr	Ponding
4/25/78	1450	0.000	0	0		0
	1516	.022	.051	0		0
	1652	.022	0	0		0
	1736	.033	.015	0		0
	2009	.033	0	0		0
	2012	.055	.440	0		0
	2038	.176	.279	0	1.79	0
	2042	.275	1.485	0	1.22	.002
	2052	.461	1.116	0	0.82	.025
	2132	.516	.083	0		0
	2349	.571	.024	0		0
	2400	.601	.164	0		0
4/26/78	0009	.626	.167	0		0
	0058	.626	0	0		0
	0118	.681	.165	0		0
	0138	.247	.199	0		0
	0158	.868	.363	0	0.48	0
	0239	1.010	.208	0	0.430	0
	0243	1.054	.660	0	0.42	.016
	0315	1.153	.186	0		0
	0336	1.186	.094	0	.390	0
	0400	1.350	.410		.360	.014
	0421	1.503	.437	0.005	.34	.030
	0456	1.624	.207		.33	0
	0629	1.734	.071			0
	0740	1.734	0	0		0
	0755	1.767	.132	0		0
	0817	1.767	0	0		0
	0835	1.789	.073	0		0
	2200	1.789	0	0		0
	2345	1.866	.044	0		0
	2400	1.883	.069	0	.30	0
TOTAL		1.883		0.005		0.087
Surface Storage Total						0.083
			Estimated RO			0.004

The purpose of the following rather lengthy write-up is to indicate how an infiltration equation would be applied to make surface runoff estimates. For those not interested in such detail, skip to page 71, Calculation of surface runoff. These complicated procedures could be computerized to facilitate the operational application of an infiltration equation. Even though storm runoff amounts are very small, this example does indicate that an infiltration based runoff prediction procedure does make reasonable estimates.

Calculation of infiltration prior to surface ponding

After rainfall starts at the soil surface, there is a time period during which the soil surface must saturate before surface ponding begins. This is equivalent to determining when the rainfall rate exceeds the soil infiltration rate.

Referring to Table 3.a.11, the initiation of ponding during the period ending at 2042 on April 24, 1978, is determined by Equation 1, as follows:

Substituting the parameter values, Table 3.a.10, into Equation 1 with F replaced by n L, gives

$$f = 0.142 \left(1 + \frac{11.69}{L}\right), \text{ (inch/hour)}$$

where, L is the wetted depth, which is calculated as

$$L = F/(0.175), \text{ (inches)}$$

F is total infiltration, and 0.175 is fillable porosity.

At time equal 2038, the rainfall of 0.176 inches of water has infiltrated. The wetted depth is thus

$$L = 0.176/0.175 = 1.01 \text{ inches}$$

and the infiltration rate at that time is

$$f = 0.142\ (1+11.69/1.01)$$

$$f = 1.79 \text{ inches/hour}$$

which clearly exceeds the rainfall rate during the period 2012 to 2038.

The next determination is whether the rainfall intensity of 1.485 in/hr in the period 2038 to 2042 exceeds the infiltration rate. First, an infiltration rate is calculated assuming that all the rainfall up to 2042 infiltrated, i. e.,

$$F = .275 \text{ inches,}$$

producing a wetted depth of

$$L = .275/.175 = 1.57 \text{ inches}$$

and an infiltration rate at 2042 of

$$f = .142\ (1+11.69/1.57)$$

$$f = 1.20 \text{ inches/hour}$$

Since the interval rainfall intensity exceeds this infiltration rate, then at sometime in the interval 2038 - 2042, surface ponding is initiated. To determine this time, the following two equations are solved by iteration. The first equation determines the amount of infiltration up to the unknown time when the rate equals the rain intensity, i. e., 1.485 in/hr.

$$F = 1.76 + \left(\frac{1.485 + 1.79}{2}\right) \frac{\Delta t}{60}$$

The second equation calculates the infiltration rate corresponding to the above calculated amount, F, which should be equal to rainfall intensity,

$$f = .142\ (1+11.69/(F/1.75)$$

When $f = 1.485$, then $2038 + \Delta t$ is the time at which surface ponding starts. For example, if we take

$$\Delta t = 1.57 \text{ min}$$

then $F = 0.219$ inches

but $f = 1.471 \neq 1.485$ in/hr, thus, the time increment must be reduced.

When taking

$$\Delta t = 1.50 \text{ min}$$

then $F = 0.217$ inches

and $f = 1.481 \approx 1.485 \approx 1.49$ inches/hour

Thus, the infiltration rate approximately equals the rainfall rate 1.50 minutes after time = 2038. The next calculation is for determining the infiltration rate at the end of the time interval, i. e., 2042. During time period 2038 - 2039.5, surface ponding occurs; and surface runoff may be generated, if the surface ponding volume is exceeded.

<u>Calculation of total surface ponding</u>

At the end of the time period 2042, the increment of infiltration during the time interval 2039.5 - 2042 is calculated by the following equations:

$$\Delta F = (\text{ave. } f)\ (2042\text{-}2039.5)/60, \text{ inches}$$

or

$$\Delta F = \left(\frac{1.49 + X}{2}\right) \frac{(2.5)}{60}$$

Also, the infiltration rate at the end of the interval is

$$f = .142\ (1 + 11.69/L)$$

where

$$L = (0.217 + \Delta F)/.175 \qquad \text{is the wetted depth.}$$

The average f during the interval is calculated as the average of the rates at 2039.5 and 2042, i. e., $(1.49 + X)/2$.

Note that

X = The assumed infiltration rate at 2042

L = Wetted depth at time 2042, i. e., $F + \Delta F = 0.217 + \Delta F$.

f = Calculated infiltration rate at time 2042.

If, at the end of the iteration process, $X = f$, then the infiltration rate at 2042 has been established.

For example,

X = 1.20 inches/hour (assumed rate at 2042)

ΔF = 0.056 inches (calculated increment of F)

L = 1.56 inches (calculated wetted depth)

f = 1.206 inches/hour (calculated infiltration rate at 2042)

$f \neq X$

and

$$X = 1.206$$

$$\Delta F = 0.056$$

$$L = 1.561$$

$$f = 1.205$$

Thus, at 2042, the infiltration rate is 1.21 in/hr. During the time increment 2038 - 2042, total infiltration increased to (0.217+.056) or 0.273 inches. The amount of surface ponding, SP, is calculated as the difference between total rainfall and infiltration during the time interval,

$$SP = I \left(\frac{\Delta t}{60}\right) - \Delta F$$

$$SP = 1.485 \left(\frac{4}{60}\right) - 0.097$$

or $$SP = 0.002 \text{ inches}$$

In this calculation, ΔF is the total infiltration during the interval 2038 to 2042, i. e., (0.217-0.176)+.056=0.097, where 0.176 is total infiltration at 2038.

The other periods of surface ponding, shown in Table 3.a.11, are calculated similarly.

<u>Calculation of surface runoff</u>

If the surface ponding exceeds surface storage, then surface runoff would be generated.

At the bottom of Table 3.a.11, total calculated surface ponding is given, together with total observed rainfall and runoff. Even though the amounts of runoff in this storm are small, the following will illustrate the process of surface ponding becoming surface runoff.

Between 2042 and 2052, 0.027 inches of surface ponding occurred. Assuming that surface storage on the watershed was 0.04 inches, then no runoff would occur.

By the next period of surface ponding, April 26, 1978, 0239 - 0243, the above surface ponding would have infiltrated, taking place during the periods of low rainfall intensity or no rainfall. The 0.016 inch of surface ponding would also remain in surface storage, which was assumed to have a capacity of 0.04 inch. Again, this surface storage would have infiltrated before the next period of surface ponding, 0400 - 0421. The total surface ponding during this period was 0.044 inch. Again, assuming 0.04 inch of surface storage, then 0.004 inch of runoff would occur. No additional periods of surface ponding were indicated, and the infiltration rate of the end of the storm was calculated to be 0.30 inch per hour.

In summary, soil water desorption data can be utilized to make reasonable estimates for the Green and Ampt infiltration equation parameters. The coverage of a number of soil textures by this data has permitted the establishment of parameter values for soil textural classes (Table 3.a.9). These values can be applied to a soil type with a profile consisting of several soil texture layers.

The example included here for calculating surface runoff indicates the type of calculations necessary. They are, obviously, quite involved; however, they could be computerized. It is proposed to do this, if improved Green and Ampt parameter values can be derived from a re-analyses of the Clapp and Hornberger data.

<u>Water Year Precipitation - Runoff Correlations</u>: Annual correlations for the Reynolds Mountain East Watershed, which has an average annual runoff of 20.5 inches, Table 3.a.2, and the Tollgate Watershed, which has an average annual runoff of 9.5 inches, Table 3.a.4, are summarized in Table 3.a.12. The Reynolds Mountain East results show the importance of using on-site precipitation in establishing reliable precipitation-runoff relationships. The valley precipitation site 076X59, about 10 miles from the watershed, produced a correlation of 0.627, while the on-site precipitation site produced a correlation of 0.913. Adding April 1 snow water content to the regression increased the multiple correlation coefficient to 0.977. Base flow and average monthly temperature for the months May-July did not improve the regression. Similar results for the Tollgate Watershed, Table 3.a.12, again show the importance of finding a good indicator station. The valley precipitation station produced a correlation of 0.629 with

TABLE 3.a.12.--Annual precipitation-runoff correlations

Parameters	Correlation Coefficient	Standard error of estimate
REYNOLDS MOUNTAIN EAST		Inches
Valley precipitation (076X59)	0.627	7.59
On-site precipitation (076X07)	0.913	3.97
April 1 snow water content	0.842	5.27
Mean December flow	0.294	9.32
Mean monthly temperature (May-July)	-0.243	9.46
On-site precipitation, snow	0.977	2.15
On-site precipitation, snow, base flow	0.978	2.18
On-site precipitation, snow, base flow, temperature	0.978	2.27
TOLLGATE		
Valley precipitation (076X59)	0.629	3.81
11 precipitation sites	0.976	2.47
5 precipitation sites	0.971	1.46
On-site precipitation (155X07)	0.921	1.91
April 1 snow water content	0.965	1.28
Mean December flow	0.462	4.34
Mean monthly temperature (May-July)	-0.183	4.81
On-site precipitation, snow	0.990	0.72
On-site precipitation, snow, base flow	0.996	0.51
On-site precipitation, snow, base flow, temperature	0.996	0.52

a standard error of 3.81 inches, while the best on-site single station correlation was 0.921 with a standard error of 1.91 inches. All eleven precipitation stations within the Tollgate drainage combined produced a larger standard error of 2.47 inches. When considering only precipitation, the lowest standard error of 1.46 was produced by using five precipitation stations. April 1 snow water content and mean December flow along with one precipitation site were significant in reducing the standard error to 0.51 inch.

Monthly Precipitation - Runoff Correlation: Monthly correlations for the Tollgate and Salmon Creek Watersheds are summarized in Table 3.a.13. The low correlation coefficients are not too surprising when one considers how the runoff occurs on these two watersheds. The Tollgate results show the problems encountered in determining precipitation-runoff relationships where a large part of the precipitation is in the form of snow. The Salmon Creek Watershed, which is a lower elevation watershed, produced somewhat better correlations during the spring months. The high correlation for August was due to unusually high precipitation in only one year. Both stations show the influence of the runoff-producing storms during December and January that usually cause the greatest floods in this region.

Soil Frost: Data were collected at eleven sites on the Reynolds Creek Experimental Watershed. There was shallow frozen soil at the higher elevations in the fall that thawed under the snow cover before spring melt. Soil frost at other locations was very shallow and intermittent, because of the warm winter temperatures.

TABLE 3.a.13.--Monthly precipitation-runoff correlations.

MONTH	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
TOLLGATE												
Correlation coefficient	.754	.644	.507	.777	.468	.501	.174	-.344	.454	.604	.166	.514
Average Precip. (Inches)	2.14	3.38	3.77	4.64	2.77	3.03	2.33	1.41	1.74	0.75	1.02	1.06
Average Runoff (Inches)	0.085	0.141	0.235	0.615	0.422	1.071	1.824	3.253	1.482	0.259	0.052	0.038
SALMON CREEK												
Correlation coefficient	.518	.411	.902	.856	-.003	.687	.572	.560	.674	-.094	.740	.007
Average Precip. (Inches)	1.43	2.42	2.56	2.89	1.61	1.89	2.12	1.57	1.79	0.39	0.80	1.02
Average Runoff (Inches)	0.049	0.091	0.259	0.631	0.369	0.617	0.548	0.323	0.125	0.027	0.024	0.017

b. Boise Front

(Boise Front Watershed runoff station locations are shown in Introduction, Figure 2.)

BOISE FRONT WATERSHEDS

Upper Maynard Gulch: Runoff from this 725-acre watershed in the 1978 water year was 5.39 inches, Table 3.b.1. Precipitation ranged from 23.8 inches near the runoff-measuring station at 3,800 feet elevation to 29.5 inches near the headwaters at 5,450 feet elevation. The peak runoff rate was 2.18 ft^3/sec on April 20. The stream did not go dry in 1978, but the flow was only about 0.01 ft^3/sec in parts of July, August, and September. There was good snow cover on most of the watershed during the winter. The watershed was grazed by cattle and sheep in 1978.

Lower Maynard Gulch: Runoff from this 644-acre watershed was 0.96 inch when runoff from the Upper Maynard Gulch Watershed was subtracted, Table 3.b.1. The peak runoff rate was 2.36 ft^3/sec on January 16. The stream at the watershed outlet was completely dry for 53 days during July, August, and September; and streamflow within the Lower Maynard Gulch Watershed showed greater inflow than outflow in all months except January, February, March, and April. Obviously, the channel in the Lower Maynard Gulch Watershed caused large streamflow losses. Precipitation ranged from 18.6 inches near the watershed outlet at 2,880 feet elevation to 23.8 inches at 3,800 feet elevation in the upper part of the drainage. The watershed was grazed by cattle in 1978.

Camp Creek: Runoff from this 717-acre watershed was 1.98 inches in 1978, Table 3.b.1. The peak runoff rate was 1.05 ft^3/sec on March 5. The stream at the runoff measuring station was completely dry from July 27 to the end of September. Precipitation, estimated from rain gages about 1½ miles west of the watershed, was about 26 inches. The watershed was not grazed by cattle in 1978.

Highland Creek: Runoff from this 988-acre watershed was 4.97 inches in 1978, Table 3.b.1. The peak runoff rate was 2.02 ft^3/sec for 12 days in March and April. The stream did not go dry in 1978, but the flow was less than 0.01 ft^3/sec in parts of July and August. Precipitation was about 27 inches, estimated from rain gages one to two miles west. The watershed was not grazed by cattle in 1978.

TABLE 3.b.1.--1978 Water year runoff by months from Boise Front watersheds.

Month	Watershed: Maynard Gulch[1/] Upper	Watershed: Maynard Gulch[1/] Lower	Watershed: Camp Creek	Watershed: Highland Creek
	inches			
Oct.	0.063	-0.058	0.000	0.103
Nov.	0.118	-0.054	0.007	0.140
Dec.	0.197	-0.031	0.076	0.278
Jan.	0.490	0.280	0.294	0.424
Feb.	0.685	0.487	0.418	0.611
Mar	1.314	0.379	0.438	1.093
Apr.	1.441	0.172	0.382	1.267
May	0.822	-0.064	0.249	0.721
June	0.162	-0.089	0.088	0.168
July	0.049	-0.040	0.030	0.069
Aug.	0.010	-0.011	0.000	0.030
Sept.	0.042	-0.015	0.000	0.064
Year Total	5.393	0.956	1.982	4.968

[1/] Minus values show streamflow losses in the channel between the runoff measuring station. The Lower Maynard runoff measuring station is about 1½ miles downstream from the Upper Maynard station.

Boise Front and Reynolds Creek Watershed Comparisons: Upper Maynard Gulch and Highland Creek Watersheds on the Boise Front, Introduction, Figure 2, have about the same elevation range as Salmon Creek and Macks Creek Watersheds on the Reynolds Creek Watershed, Introduction, Figure 1, Table 3.b.2. However, the drainage areas, precipitation, and yearly runoff amounts are much different. The relationship between monthly runoff amounts in water years 1977 and 1978 from Upper Maynard Gulch and Highland Creek is

$$Y = -0.075 + 1.221 X_1$$

where, Y is monthly runoff from Maynard Gulch, and X_1 is monthly runoff from Highland Creek. The correlation coefficient, r, is 0.995 for this 24-month record. The relationship between monthly runoff from Upper Maynard Gulch and Salmon Creek is

$$Y = 0.018 + 1.484 X_2$$

where, X_2 is the monthly runoff from Salmon Creek, r = 0.991. The relationship between monthly runoff from Upper Maynard Gulch and Macks Creek is

$$Y = 0.060 + 1.448 X_3$$

where, X_3 is monthly runoff from Macks Creek, r = 0.974. These relationships are shown graphically in Figure 3.b.1. The relationships are useful in estimating monthly runoff from Boise Front Watersheds with a short period of record, based upon long-term records from Reynolds Creek Watersheds. However, reliable daily runoff and precipitation relationships have not been established between the two areas about 60 miles apart.

Soil Frost: Data were collected at the four rain gage sites throughout the winter. The winter temperatures were above normal and, consequently, the only soil frost was very shallow and intermittent.

TABLE 3.b.2.--Elevation, drainage area, precipitation, and runoff for Boise Front and Reynolds Creek watersheds.

Watershed	Elevation range *feet*	Drainage area *acres*	1978 Precipitation *inches*	1978 Runoff *inches*
Boise Front				
Upper Maynard Gulch	3720-5900	725	26.7	5.39
Highland Creek	3630-5900	988	27.0	4.97
Reynolds Creek				
Salmon Creek	3680-6300	8990	23.4	3.41
Macks Creek	3710-6200	7846	24.6	3.01

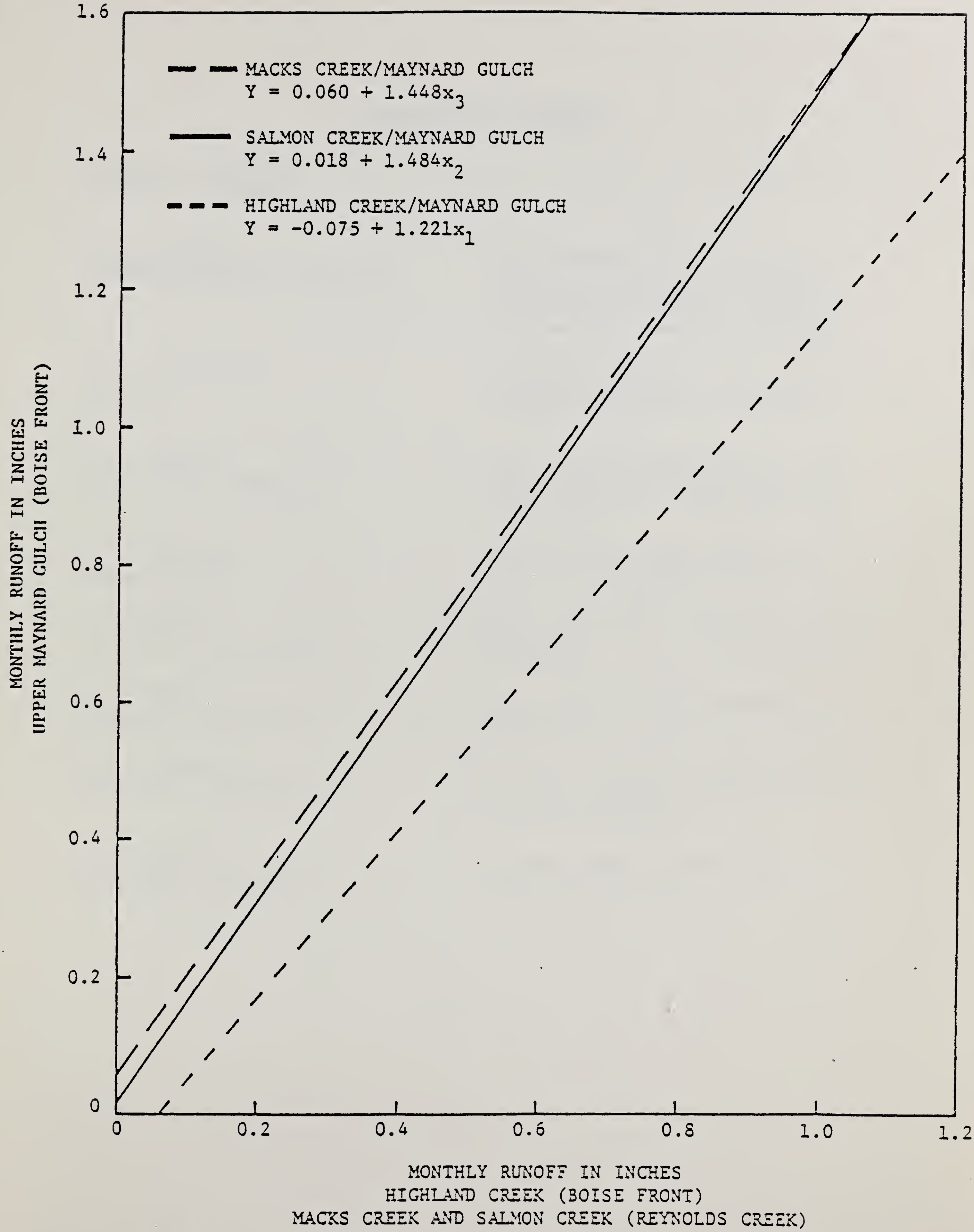

Figure 3.b.1.--Monthly runoff relationships between watersheds on Boise Front and Reynolds Creek, 1977-1978.

4. EROSION AND SEDIMENT

Personnel Involved

C. W. Johnson, Research Hydraulic Engineer	Plan programs and procedures; design and construct facilities for sediment studies; perform analyses and summarize results.
G. R. Stephenson, Geologist	Determine geologic and geomorphic parameters related to sediment yield.
C. L. Hanson, Agricultural Engineer	Test various components in sediment models most applicable to rangelands.
R. L. Engleman, Mathematician	Perform data compilation and assist in analyses.
J. P. Smith, Hydrologic Technician	Data collection, compilation, and analyses.
J. H. Harris, Biological Technician	Data collection and sediment analyses.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and radio telemetry systems.
M. S. Thomson, Hydrologic Technician	Sediment sampling and data compilation.

a. Reynolds Creek

(Reynolds Creek Experimental Watershed station locations are shown in the Introduction, Figure 1.)

MICROWATERSHEDS

Flats: No sediment samples were taken at this station in 1968, because runoff was not sufficient to fill sediment sampler bottles. Sediment amounts were obviously insignificant from the only runoff on April 26, 1978.

The most severe thunderstorm of the year on the Reynolds Creek Watershed was on the afternoon of July 8, 1978, about 1½ miles east of the Flats. This storm caused visible hillslope erosion and peak streamflow was 110 ft^3/sec from 38 acres, 1850 $ft^3/sec/mi^2$, at the storm center. The measured soil loss from a 40 percent slope 85 feet long was 52 tons/acre. The cover on the slope was only 5-10 percent. Some rills were about 30 inches wide and 2 inches deep at the bottom of the slope. Peak streamflow about 3/4 mile downstream from the storm center was 340 ft^3/sec from 717 acres, about 300 $ft^3/sec/mi^2$. The nearest precipitation station, about 1½ miles west of the severe erosion, recorded only 0.15 inch during this storm; on-site precipitation was not measured.

Nancy Gulch: No sediment samples were taken at this station in 1968, because runoff was limited to a trickle on April 26 and 27. Sediment amounts were insignificant from this station.

SOURCE WATERSHED

Reynolds Mountain East: Total sediment yield from this 100-acre watershed in 1978 was 12.1 tons, 89 percent of the 11-year mean (Table 4.a.1). The maximum suspended sediment concentration was 580 mg/l, when peak runoff occurred on May 14. Figure 4.a.1 shows 1978 data compared with previous records (Table 4.a.1).

TABLE 4.a.1.--Sediment yield in tons at Reynolds Creek Watershed stations, 1978 water year.

Year	Reynolds Mountain East	Macks[1/] Creek	Dobson[1/] Creek	Reynolds Creek at Tollgate	Reynolds[1/] Creek at Outlet
1967	--	--	--	11275	13503
1968	5.5	393	--	1965	4334
1969	17.0	6332	--	12994	39336
1970	31.1	3585	--	7242	15369
1971	18.1	5833	--	9771	28641
1972	18.3	5414	--	8838	37396
1973	9.4	1147	--	1203	2415
1974	10.3	1214	--	2774	5762
1975	14.2	1949	--	7867	9860
1976	12.4	646	--	2546	1430
1977	1.0	7	25	51	3257
1978	12.1	554	393	2797	8256
MEAN	13.6	2461	--	5777	14130

1/ Suspended Sediment only.

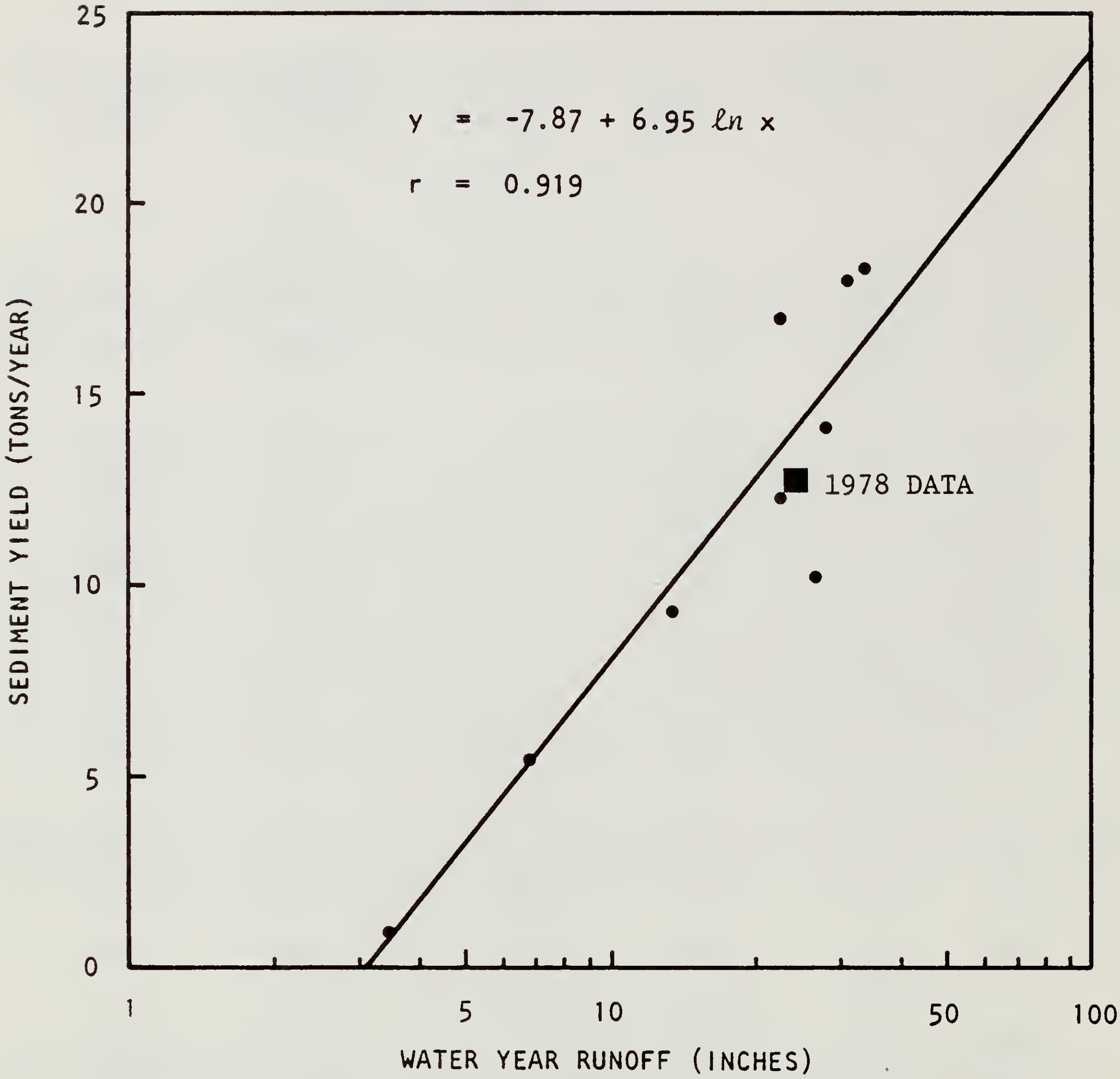

Figure 4.a.1. --Runoff-sediment yield relationship, Reynolds Mountain East Watershed, 1968-77.

TRIBUTARY WATERSHEDS

Macks Creek: Suspended sediment yield from this 7846-acre watershed was 554 tons in 1978, about 23 percent of the 11-year mean, Table 4.a.1. This lower than normal yearly sediment yield was associated with slightly above normal runoff and below normal peak streamflow. Over 54 percent of the yearly sediment yield was from the April 25-27 storm. Bedload sediment was not measured in 1978.

Dobson Creek: Suspended sediment from this 3842-acre watershed was 393 tons in 1978, Table 4.a.1. About 37 percent of the yearly sediment yield was from the April 25-27 storm. Since sediment records began at this station in 1977, there is no reliable data base for comparing 1978 sediment yields.

MAIN STEM WATERSHEDS

Reynolds Creek at Outlet: Suspended sediment yield from the Reynolds Creek Watershed, 90.24 mi^2, was 8256 tons in 1978, 58 percent of the 12-year mean, Table 4.a.1. About 62 percent of the yearly sediment yield was during the April 25-27 storm. The maximum sediment concentration was 6365 mg/l on April 26 with the peak streamflow.

Reynolds Creek at Tollgate: Total sediment yield from the Reynolds Tollgate Watershed, 21 mi^2, was 2797 tons, 48 percent of the 12-year mean, Table 4.a.1. About 46 percent of the yearly sediment yield was during the April 25-27 storm. The maximum sediment concentration was 5995 mg/l on April 26 with the peak streamflow. Bedload was about 18 percent of total sediment yield, and 74 percent of the yearly bedload was transported during the April 25-27 storm.

BEDLOAD SEDIMENT SAMPLING

Bedload sediment measurements were made at only three stations in 1978, because of limited personnel during the April 25-27 storm--the only time when bedload transport rates were high enough for meaningful sampling. Sediment transport and particle-size measurements in 1978 are well represented in previous data reported by Johnson and Smith (1977). Sediment transport and channel characteristics were not analyzed in 1978.

REDUCTION IN STREAM SEDIMENT LOADS BY IRRIGATION

A study of the effects of diverting sediment-laden water for irrigation between the Reynolds Creek Tollgate and Outlet stations, 1967-77, showed that, on the average, 620 tons of sediment per year was removed by the irrigation systems. This was about 17 percent of the incoming sediment. Deposition on cropland, assuming even sediment distribution, was about 0.08 mm/year on 1700 acres. Sediment concentrations ranged from near zero to nearly 59,000 mg/l during the irrigation season.

RANGELAND EROSION POTENTIAL BY THE USLE

The Universal Soil Loss Equation (USLE) and rangeland cover data from nine study sites were used to study the effects of grazing and brush control on potential soil loss, 1972-78. Three sites with rocky soils and sagebrush 8-10 inches high showed 20 percent greater computed soil loss on grazed areas than on ungrazed areas. Five sites with sagebrush 18-24 inches high showed 54 percent greater computed soil loss on grazed areas. Computed soil loss was 38 percent greater on areas sprayed to kill sagebrush than on untreated areas, and was 134 percent greater on areas where sagebrush was cut and removed at the beginning of the study. Computed soil loss was 122 percent greater on a heavily grazed area (about 80-90 percent utilization) than on a comparable ungrazed area. Measured sediment yields from watersheds where some study sites were located showed sediment delivery ratios from 0.15 to 0.47, based on computed soil losses.

There was no progress in using Reynolds Creek sediment yield data to thoroughly test USLE and PSIAC (Pacific Southwest Interagency Committee) procedures on sagebrush rangelands.

b. Boise Front Results

(Boise Front runoff and sediment sampling station locations are shown in the Introduction, Figure 2.)

Upper Maynard Gulch: Suspended sediment yield from this 725-acre watershed was 6.6 tons in 1978, Table 4.b.1. Sediment concentrations did not exceed 100 mg/l, even during the April 20 peak runoff. Bedload transport, evidenced by weir pond deposition, was estimated to be less than 0.5 ton during the year. There was no visible evidence of erosion, except on roads where runoff was concentrated.

Lower Maynard Gulch: Suspended sediment yield, measured at the Lower Maynard Gulch station, includes sediment from Upper Maynard Gulch. The suspended sediment yield from a total of 1369 acres was 8.9 tons in 1978, Table 4.b.1. Sediment concentrations were less than 100 mg/l during peak runoff, January 15-18. Bedload transport, observed in weir pond deposition, was estimated to be about 0.5 ton during the year. Obviously, the thick growth of willows lining the channel effectively filters sediment when no flooding occurs, such as in 1978.

Camp Creek: Suspended sediment yield from this 717-acre watershed was 1.9 tons in 1978, Table 4.b.1. The maximum observed suspended sediment concentration was 714 mg/l on April 16 at slightly less than peak streamflow. Estimated peak sediment concentrations were about 1000 mg/l. Slight bedload transport was observed moving through the Parshall Flume, but there are no bedload sampling facilities at this station.

Highland Creek: Total sediment yield from this 988-acre watershed was 99 tons in 1978, Table 4.b.1. Amounts were determined from frequent suspended sediment samples and occasional bedload transport samples. The maximum observed suspended sediment concentration was 3175 mg/l on January 15. The maximum bedload transport was 1.8 kg/min on April 16. Bedload was about 35 percent of the total yearly sediment yield and the mean bedload particle-size was about 0.9 mm. The bedload material filled several beaver dams downstream from the sampling station.

TABLE 4.b.1.--Sediment yield from Boise Front Watersheds, 1978 Water Year

Month	Watershed			
	Upper Maynard Gulch	Lower[1/] Maynard Gulch	Camp Creek	Highland Creek
	tons			
October	0.01	0	0	0.46
November	0.14	0.03	0	0.72
December	0.33	0.13	0.07	2.29
January	0.55	0.99	0.68	13.50
February	0.62	1.04	0.30	8.24
March	1.10	2.46	0.39	23.49
April	2.93	2.99	0.28	38.85
May	0.83	1.15	0.10	10.82
June	0.05	0.06	0.04	0.23
July	0.02	0.01	0.01	0.13
August	0	0	0	0.01
September	0.01	0.01	0	0.07
Year Total	6.59[2/]	8.87[2/]	1.87[2/]	98.81

1/ Drainage area includes Upper Maynard Gulch

2/ Suspended sediment only.

Erosion Studies: Since there was little evidence of erosion on steep, barren hillslopes in 1978, no soil loss surveys were made on previously active erosion sites. Generally, streamflow sediment measurements verified that erosion rates were low in 1978. Additional data to determine factors in the Universal Soil Loss Equation, applicable to the Boise Front, were not adequate in 1978 for meaningful analysis in this report. Also, arrangements for use of a rainulator in evaluating USLE parameters were unsuccessful.

5. WATER QUALITY

Personnel Involved

G. R. Stephenson, Geologist	Responsible for coordinating activities with cooperators. Design collection network and responsible for project completion.
J. F. Zuzel, Hydrologist	Responsible for statistical analyses of data, water quality modeling, and shares the responsibility for aquatic sampling.
J. H. Harris, Biological Technician	Responsible for collection of water samples and laboratory analyses.
M. S. Thomson, Hydrologic Technician	Shares the responsibility for field operations and water sampling.

a. Reynolds Creek[1/]

A total of eight sites were monitored this year for biological indicators. Only one set of samples from two sites was analyzed for complete chemical concentrations. Because of the increased cost for outside chemical analyses, it was decided to discontinue this part of the program until our own lab was completed. Early in 1979, we will have the capabilities for complete water chemistry analyses.

The lack of chemical data for the year was not considered significant, because of the 5-year record already on hand for Reynolds Creek sites. Additional COD and total dissolved solid determinations were made at all sites. Since T.D.S. is an estimate of all chemical constituents in solution, it does relate to the total chemistry of each sample. It does not, however, give the individual concentration of each chemical constituent.

Figure 5.a.1 gives the location of the sampling sites on the Reynolds Creek Watershed, and Table 5.a.1 gives a summary of the data for the year for all sites.

A comparison of the 1977 and 1978 data reflects mainly the differences in streamflow characteristics between the two years. The low streamflow in 1977, brought about by the drought conditions that year, resulted in higher concentrations of most chemical parameters (see Interim Report No. 8) and very low suspended sediment concentrations. This is most significant for electrical conductivity and total dissolved solid measurements. Streamflow in 1978 was near normal for the hydrologic record at Reynolds Creek. As a result, the 1978 water chemistry data compare well with the 1972-1976 results, with nearly the same concentrations. Although not a large sediment production year, 1978 suspended sediment concentrations were much greater than for 1977. Bacteriological data follow about the same trends as the suspended sediment concentrations in comparison of results for 1977 and 1978.

The comparison of these results shows that the 1977 drought conditions caused a significant reduction in the quality of streamflow on the Reynolds Creek Watershed, but did not carry over into 1978. All quality parameters in 1978 compare well with the pre-1977 results.

[1/] Reynolds Creek site locations on Introduction, Figure 1.

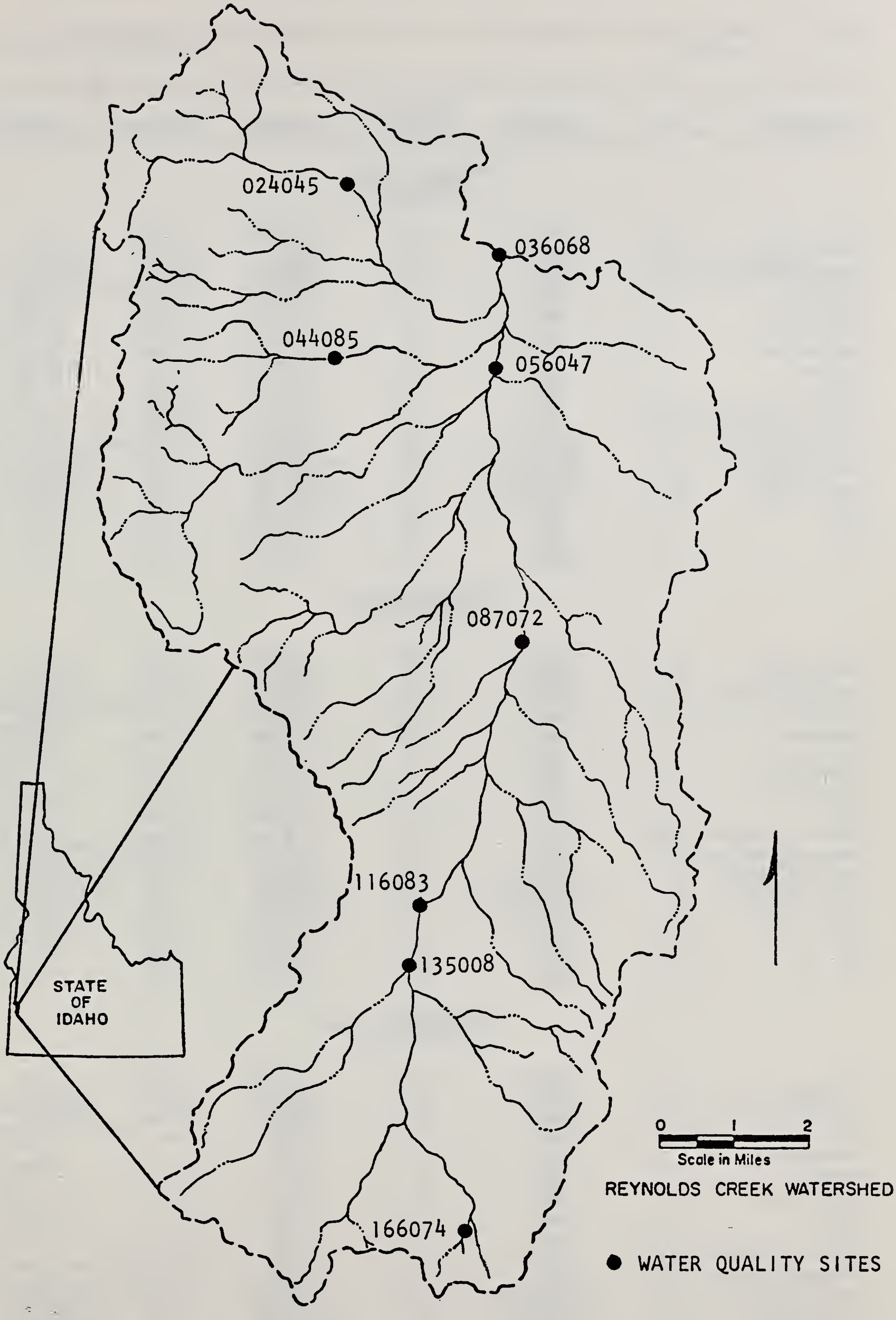

Figure 5.a.1.--Location of water sampling sites for water quality determination.

TABLE 5.a.1--Water quality characteristics, Reynolds Creek Watershed sampling sites, 1977-78.

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		REYNOLDS OUTLET (036068)			
pH	units	27	9.20	7.50	8.35
Conductivity	μmhos	27	3100.00	110.00	732.00
Dissolved solids	mg/l	27	2139.00	80.00	505.08
Calcium	mg/l	1	20.84	20.84	20.84
Magnesium	mg/l	1	7.78	7.78	7.78
Sodium	mg/l	1	17.93	17.93	17.93
Phosphorous	mg/l	1	1.96	1.96	1.96
Nitrate	mg/l	1	0.11	0.11	0.11
SiO_2	mg/l	1	13.10	13.10	13.10
Sodium adsorption ratio	ratio	1	0.85	0.85	0.85
Suspended solids	mg/l	26	307.50	110.00	51.40
Total coliform	cts/100 ml	28	380.00	0.00	93.70
Fecal coliform	cts/100 ml	28	323.00	0.00	47.60
Fecal strep	cts/100 ml	27	302.00	4.00	74.89
COD	mg/l	19	23.30	4.80	12.83
BOD	mg/l	25	3.00	0.50	1.48
DO	mg/l	26	11.00	7.00	8.6
		TOLLGATE WEIR (116083)			
pH	units	26	8.60	7.55	8.01
Conductivity	μmhos	26	300.00	54.00	133.27
Dissolved solids	mg/l	26	207.00	37.26	91.95
Calcium	mg/l	1	12.83	12.83	12.83
Magnesium	mg/l	1	6.08	6.08	6.08
Sodium	mg/l	1	6.67	6.67	6.67
Phosphorous	mg/l	1	1.17	1.17	1.17
Nitrate	mg/l	1	0.04	0.04	0.04
SiO_2	mg/l	1	2.50	2.50	2.50
Sodium adsorption ratio	ratio	1	0.38	0.38	0.38
Suspended solids	mg/l	18	63.00	2.00	18.48
Total coliform	cts/100 ml	27	390.00	0.00	97.93
Fecal coliform	cts/100 ml	27	220.00	0.00	38.56
Fecal strep	cts/100 ml	22	390.00	0.00	66.54
COD	mg/l	8	5.20	0.00	2.21
BOD	mg/l	10	0.50	0.00	0.20
DO	mg/l	25	10.50	7.50	8.68
		UPPER SALMON (024045)			
pH	units	14	8.80	7.70	8.32
Conductivity	μmhos	13	200.00	90.00	159.92
Dissolved solids	mg/l	13	138.00	62.00	110.34
Calcium	mg/l	--	--	--	--
Magnesium	mg/l	--	--	--	--
Sodium	mg/l	--	--	--	--
Phosphorous	mg/l	--	--	--	--
Nitrate	mg/l	--	--	--	--
SiO_2	mg/l	--	--	--	--
Sodium adsorption ratio	ratio	--	--	--	--
Suspended solids	mg/l	3	12.40	2.00	5.8
Total coliform	cts/100 ml	15	920.00	12.00	193.73
Fecal coliform	cts/100 ml	15	820.00	0.00	90.13
Fecal strep	cts/100 ml	14	340.00	4.00	111.85
COD	--	--	--	--	--
BOD	--	--	--	--	--
DO	mg/l	11	10.00	7.00	8.23

TABLE 5.a.1.--continued

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		COTTLE CREEK (044085)			
pH	units	11	8.98	8.00	8.59
Conductivity	µmhos	10	480.00	120.00	257.00
Dissolved solids	mg/1	10	331.00	82.80	180.88
Calcium	mg/1	--	--	--	--
Magnesium	mg/1	--	--	--	--
Sodium	mg/1	--	--	--	--
Phosphorous	mg/1	--	--	--	--
Nitrate	mg/1	--	--	--	--
SiO_2	mg/1	--	--	--	--
Sodium adsorption ratio	ratio	--	--	--	--
Suspended solids	mg/1	1	2.00	2.00	2.00
Total coliform	cts/100 ml	12	1148.00	0.00	234.58
Fecal coliform	cts/100 ml	12	976.00	0.00	108.17
Fecal strep	cts/100 ml	11	255.00	4.00	107.00
COD	mg/1	--	--	--	--
BOD	mg/1	--	--	--	--
DO	mg/1	8	10.00	7.00	8.0
		LOWER REYNOLDS (056047)			
pH	units	25	8.91	7.85	8.40
Conductivity	µmhos	25	3300.00	100.00	642.38
Dissolved solids	mg/1	25	2277.00	69.00	443.24
Calcium	mg/1	--	--	--	--
Magnesium	mg/1	--	--	--	--
Sodium	mg/1	--	--	--	--
Phosphorous	mg/1	--	--	--	--
Nitrate	mg/1	--	--	--	--
SiO_2	mg/1	--	--	--	--
Sodium adsorption ratio	ratio	--	--	--	--
Suspended solids	mg/1	22	89.00	2.50	29.50
Total coliform	cts/100 ml	26	1680.00	0.00	216.27
Fecal coliform	cts/100 ml	26	1220.00	0.00	108.07
Fecal strep	cts/100 ml	25	364.00	2.00	110.84
COD	mg/1	19	20.20	6.10	13.15
BOD	mg/1	23	3.00	1.00	1.55
DO	mg/1	23	10.00	7.00	9.13
		NETTLETON BRIDGE (087072)			
pH	units	24	8.60	7.80	8.11
Conductivity	µmhos	24	440.00	70.00	197.50
Dissolved solids	mg/1	24	303.60	48.30	136.28
Calcium	mg/1	--	--	--	--
Magnesium	mg/1	--	--	--	--
Sodium	mg/1	--	--	--	--
Phosphorous	mg/1	--	--	--	--
Nitrate	mg/1	--	--	--	--
SiO_2	mg/1	--	--	--	--
Sodium adsorption ratio	ratio	--	--	--	--
Suspended solids	mg/1	4	64.50	3.50	27.20
Total coliform	cts/100 ml	25	1240.00	0.00	131.03
Fecal coliform	cts/100 ml	25	1042.00	0.00	103.88
Fecal strep	cts/100 ml	24	1680.00	0.00	194.09
COD	mg/1	19	12.70	0.00	6.51
BOD	mg/1	21	2.00	0.00	0.76
DO	mg/1	23	10.50	7.00	8.24

TABLE 5.a.1.--continued

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		BELOW DOBSON (135008)			
pH	units	27	8.70	7.20	7.95
Conductivity	µmhos	27	475.00	49.00	121.85
Dissolved solids	mg/l	27	327.75	33.81	84.08
Calcium	mg/l	--	--	--	--
Magnesium	mg/l	--	--	--	--
Sodium	mg/l	--	--	--	--
Phosphorous	mg/l	--	--	--	--
Nitrate	mg/l	--	--	--	--
SiO_2	mg/l	--	--	--	--
Sodium adsorption ratio	ratio	--	--	--	--
Suspended solids	mg/l	8	20.40	2.00	8.44
Total coliform	cts/100 ml	28	1120.00	0.00	158.60
Fecal coliform	cts/100 ml	28	820.00	0.00	71.57
Fecal strep	cts/100 ml	27	270.00	0.00	66.74
COD	mg/l	18	12.10	0.00	3.96
BOD	mg/l	25	2.00	0.00	0.38
DO	mg/l	25	11.00	7.00	9.02
		REYNOLDS MOUNTAIN WEIR (166074)			
pH	units	17	8.40	6.75	7.50
Conductivity	µmhos	17	90.00	17.00	40.65
Dissolved solids	mg/l	17	62.10	11.70	28.04
Calcium	mg/l	--	--	--	--
Magnesium	mg/l	--	--	--	--
Sodium	mg/l	--	--	--	--
Phosphorous	mg/l	--	--	--	--
Nitrate	mg/l	--	--	--	--
SiO_2	mg/l	--	--	--	--
Sodium adsorption ratio	ratio	--	--	--	--
Suspended solids	mg/l	12	140.80	1.00	16.80
Total coliform	cts/100 ml	18	125.00	0.00	60.83
Fecal coliform	cts/100 ml	18	52.00	0.00	12.89
Fecal strep	cts/100 ml	17	1820.00	0.00	178.65
COD	--	--	--	--	--
BOD	--	--	--	--	--
DO	mg/l	16	10.50	6.00	8.22

SUSPENDED SEDIMENT VERSUS FECAL COLIFORM CONCENTRATION DURING RUNOFF

The 1978 Annual Work Plan called for a study to determine bacterial concentrations associated with suspended sediment during major runoff events. Results would help to account for the differences in free coliform bacteria from those attached to suspended sediment particles during storm flow. No significant runoff events with high enough sediment concentrations occurred at the sampling sites to warrant this study for this year.

SOIL BIOLOGICAL ACTIVITY

Soil biological activity investigations were to continue this year with cooperation from Boise State University. Cooperative funds for this investigation were not available this year, so the study has been delayed.

SOURCES OF BACTERIAL INDICATORS

A part of the present 5-year plan is to develop information on sources of indicator bacteria in streamflow for the Reynolds Creek Watershed for different management and natural environmental conditions. Most of this work has been completed and reported in previous reports and will be summarized here. Fecal coliform concentrations were used as bacterial indicators.

Fecal coliform counts were always found to be higher along stream segments where cattle have unrestricted access. A direct relationship was always evident between cattle activity and fecal coliform concentration. Even though management practices varied, as soon as cattle are turned into fields where streams are the predominant source of drinking water, fecal coliform counts increased rapidly to high levels of concentration. Fecal coliform counts exceed water quality standards for the Reynolds Creek stream classification only 5 percent of the time at rangeland sites, but as much as 20 percent of the time for stream segments along winter feeding pastures.

Fecal coliform counts were found to be very low to zero in soils in moderately heavily grazed upland range, and were found to decrease rapidly over short distances downslope from "cowpies". This is a good indication that it is mostly the concentrated cattle activity immediately adjacent to or directly in streams, causing elevated indicator counts.

Figure 5.a.2 gives the geometric mean of fecal coliform counts at 11 sites along the main channel of Reynolds Creek over a 4-year period. The location of these sites is found on Figure 5.a.3. Sites 1, 5, 14, and 15 are located on channel segments, which are adjacent to pastures where cattle are fed during winter months; or, as in the case of Site 1, the entire year. At all four of these sites, cattle have free access to the stream for drinking water. Site 3, although located on rangeland, is only a short distance downstream from a pasture and is influenced by pasture runoff. Site 22 is located at the headwaters of Reynolds Creek in a small area of open range, where cattle concentrate for drinking water.

For the management and land-use practices on Reynolds Creek and adjacent areas, the fecal coliform concentration line of 30 counts/100 ml separates the pasture sites from the rangeland sites for all data collected over the 4-year period. Even at locations where cattle congregate for water and shade, such as at site 22, the mean value of the counts did not exceed 30. This indicates that the rangeland portion of Reynolds Creek is not the major contributor to bacterial indicators of stream pollution.

Another significant factor, which can be seen on Figure 5.a.2, is that at sites where elevated counts do occur, the concentrations are reduced rapidly downstream. This is particularly true along stretches of channel where cattle have very limited or no access, such as steep-walled canyons or areas in limited grazing systems. Sites 16 and 21 are located along segments of channel in steep-walled canyons (Site 21) and in allotments with very limited periods of grazing and reduced numbers of cattle (Site 16). Site 3 is also a limited access site downstream from a pasture site. All these sites show a reduction in bacterial indicator concentrations from sites upstream.

From this data, it would seem that the source of bacterial pollution indicators are overwhelmingly cattle; but, under rangeland conditions, the pollution is not significant. Even along stream segments where elevated counts do occur, self purification, resulting in reduced concentrations of fecal coliform counts, takes place rapidly downstream until additional input occurs. The major sources of fecal coliform concentrations, which cause pollution problems along Reynolds Creek, are the pasture sites where cattle are fed during the winter months; or, as in some cases, the entire year. Elevated counts well in excess of water quality standards occur quite frequently. Bacterial indicators related to wildlife and "wild" horses are not significant in Reynolds Creek.

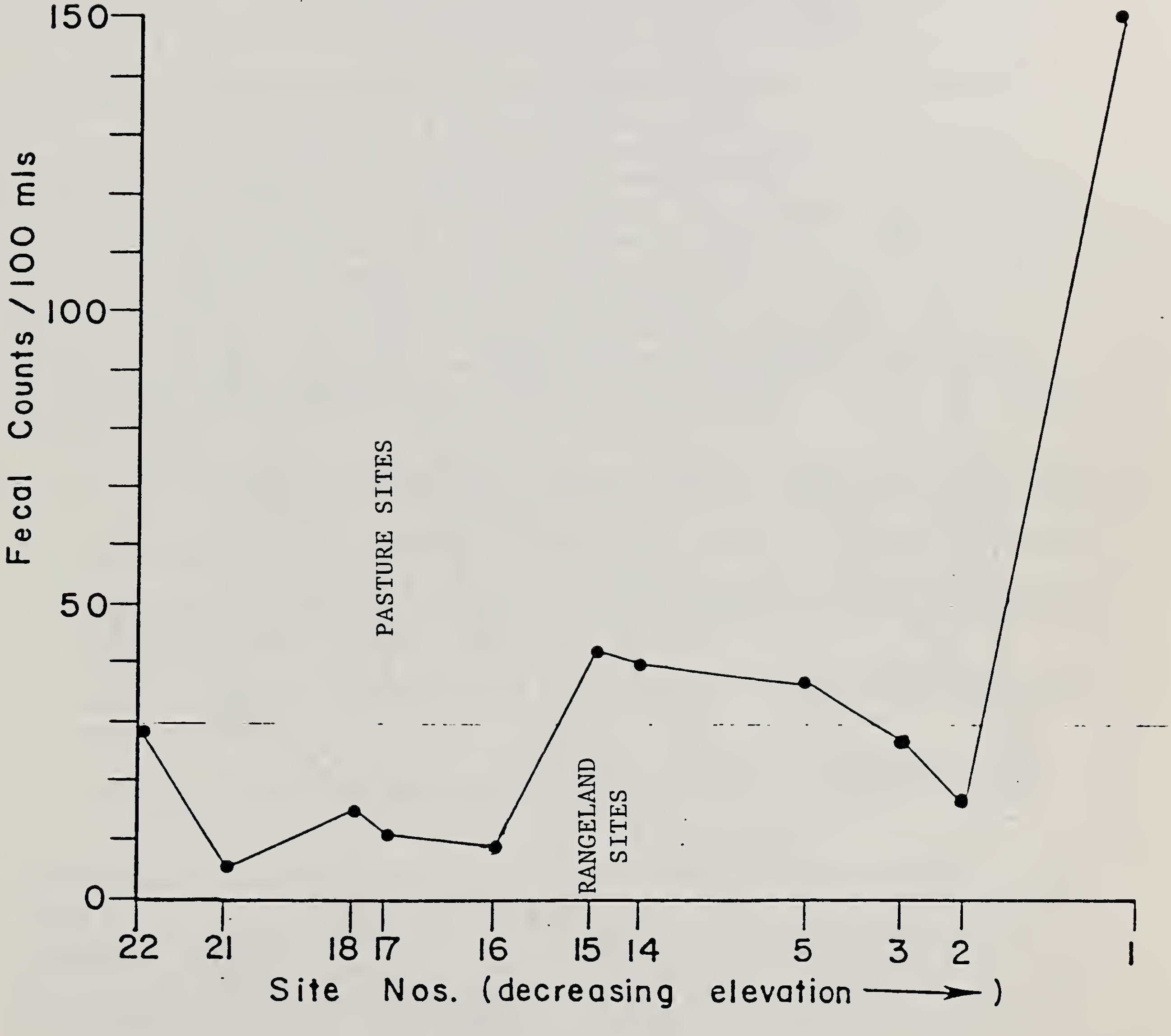

Figure 5.a.2 --Geometric mean of fecal coliform concentrations at sampling sites along Reynolds Creek.

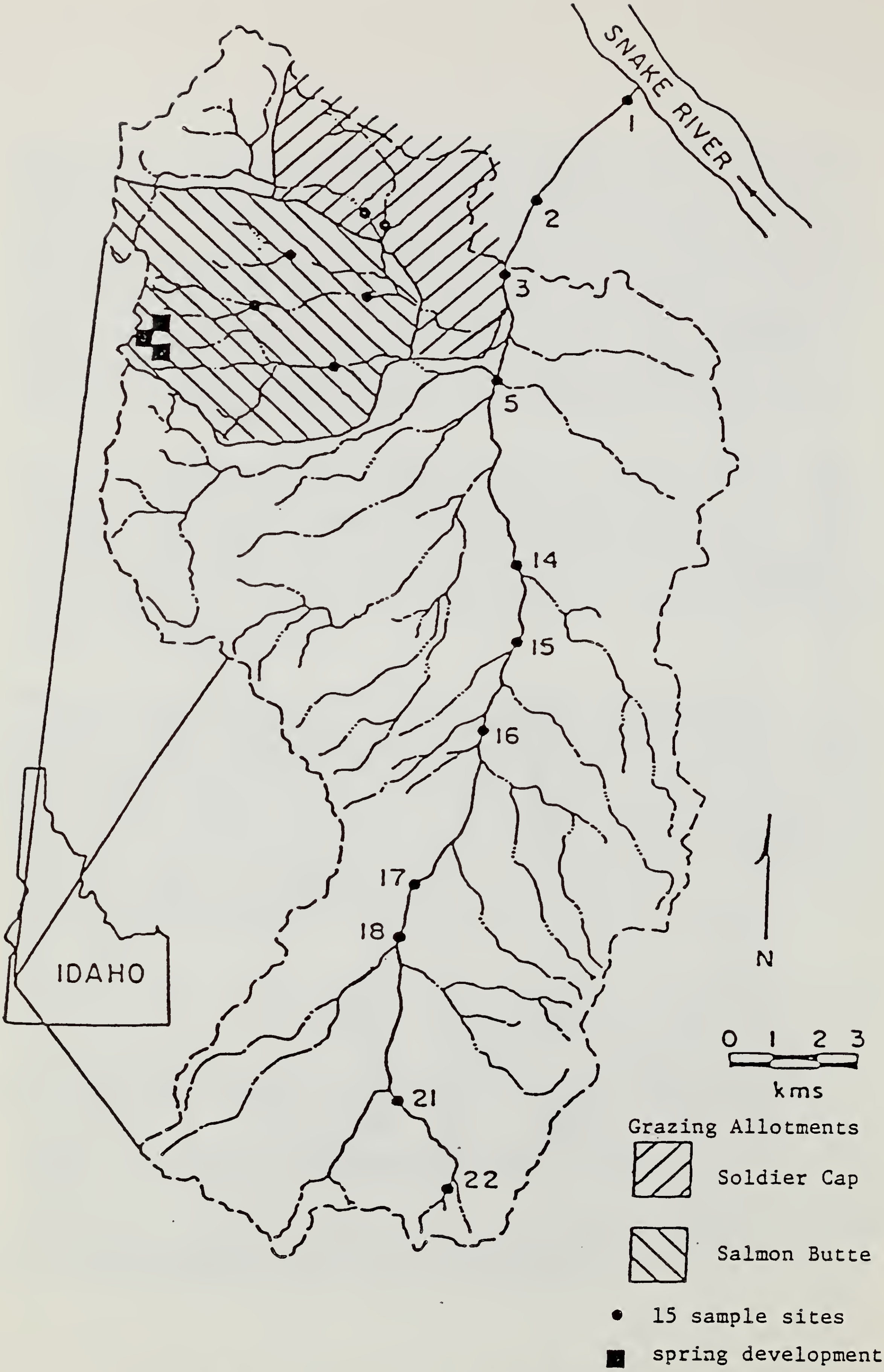

Figure 5.a.3.--Index map of deferred grazing allotments and water quality sampling sites.

AQUATIC INSECT INVESTIGATIONS

The work plan called for investigating the effects of pesticides on aquatic insects as a result of grasshopper eradication. Since no significant infestation occurred in 1978, no spraying program was necessary.

RECOMMENDED MANAGEMENT PRACTICES FOR IMPROVED QUALITY OF STREAMFLOW

Water quality data collected from 24 sites over the past 5 years was reviewed for the purpose of recommending management practices. Previous annual and progress reports have listed preliminary recommendations. From the information given in previous reports and within this report, the major source of pollution along Reynolds Creek is cattle; and the major indicator of this source is microbiological--specifically fecal coliform bacteria. The following management practices are those considered the most practical and effective for improving downstream water quality from upstream grazing for the conditions prevailing along Reynolds Creek.

For livestock grazing on rangeland, greater emphasis should be given to:

1. Developing springs and shade upland, away from free-flowing streams.

2. Transporting water for livestock by pipeline or ditch from streams or wells to remote sites away from streams.

3. Salt and mineral blocks should be located in upland areas away from major streams.

4. Livestock should not be concentrated in holding corrals adjacent to streams.

For livestock wintering operations on irrigated pastures and hay fields, it has been suggested that holding ponds can be developed at lower end of fields to increase infiltration, thereby, eliminating direct runoff from the streams. It has also been suggested that buffer zones of heavy vegetative cover between lower end of fields and adjacent streams can be used to increase infiltration, thereby, reducing nutrients and bacteria in runoff.

One study has been made to verify the effect of spring developments in upland areas on reducing pollution in free-flowing streams. In the deferred grazing system in the northwest portion of Reynolds Creek (hatchered areas shown in Figure 5.a.3), approximately 1000 head of cattle are grazed in fenced allotments each year for 2- to 4-week periods. Water samples have been collected and analyzed for 4 years from stream sites within these allotments. In 1976, a spring development was constructed in the upper reaches of the Salmon Butte allotment.

The average fecal coliform concentrations from all samples at all sites for each year are given on Figure 5.a.4 for the Salmon Butte and Soldier Cap allotments. Following construction of the spring, annual average fecal coliform concentration for the Salmon Butte allotment decreased, except for 1977. The 1976-77 winter drought conditions resulted in low spring runoff in this area, but summer storms and resulting runoff concentrated the fecal coliform bacteria in the water, giving the higher concentration in 1977. Data for the Soldier Cap allotment are given on Figure 5.a.4 for comparison, as the stream is the major source of stock water in this allotment.

Even though the general trend for fecal coliform concentration in the Salmon Butte allotment is down (except for 1977), a more quantitative expression can be made by looking at the ratio of counts for the Soldier Cap versus Salmon Butte allotments. From 1975 through 1978, the ratios increase from 1.33; 1.92; 2.04; and 3.89, respectively. Except for the spring development in the Salmon Butte allotment, all other factors remain equal through these 4 years. These results help verify the premise that these upland spring developments are a successful management tool for reducing sources of pollution in rangeland watersheds.

WATER QUALITY MODEL

The basic model now being tested on Reynolds Creek was obtained from the Department of Civil Engineering, Water and Air Resources Division, University of Washington. It has the advantage of being simple to use, needs only readily available inputs, and requires only 162 K core storage. The model is a series of subroutines; and, thus, can be run on a smaller computer, using overlay techniques.

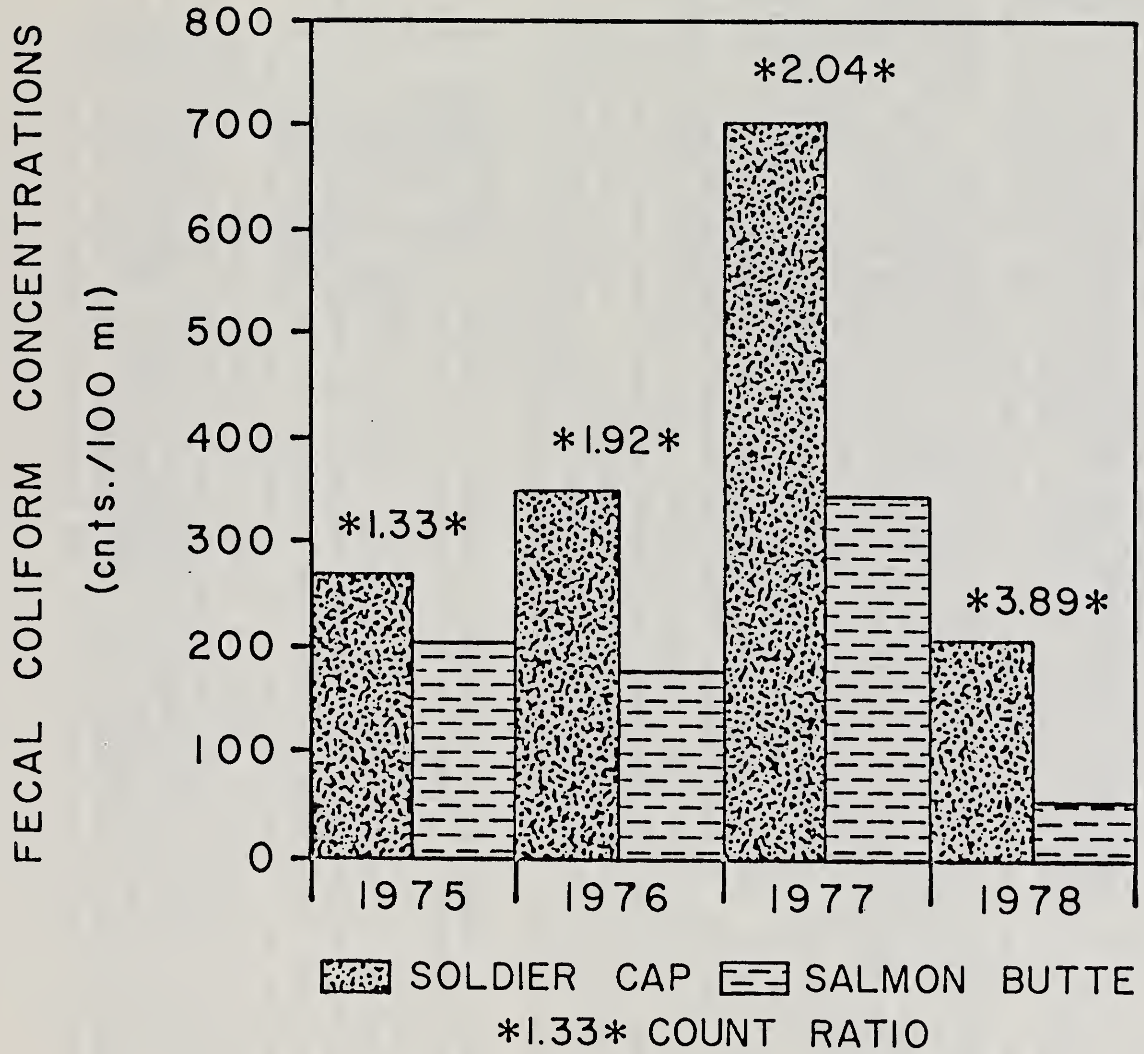

Figure 5.a.4.--Average annual fecal coliform concentration for Soldier Cap and Salmon Butte allotments. Reynolds Creek Watershed, 1975-78.

Water temperature and dissolved oxygen are probably the most significant variables in any body of water. Water temperature alone has a significant impact on rates of chemical and biological reactions. Fish and other aquatic organisms are able to adapt only to a narrow range of water temperature, and large changes in temperature can be lethal to many organisms. The result of this would be a change in the biological, as well as the chemical composition, of the lake or stream. Oxygen is, of course, essential to aquatic life; and, as in the case of water temperature, aquatic organisms are able to adapt only to a narrow range of dissolved oxygen. For example, 5 mg per liter are a minimum requirement for most fish species, while trout require a minimum of 7 mg per liter. Since the solubility of oxygen is temperature dependent, the combined effects of the temperature and oxygen regimes will determine the numbers and species of aquatic organisms present in a stream or lake. In other words, a change in the water temperature regime will result in a change in the oxygen regime. This will, in turn, affect the number and species of aquatic organisms present. The situation can occur from releases of warmer water from irrigation return flow from agricultural sources, which may be high in BOD and low in dissolved oxygen. These changes are typical of most rivers and streams in the semiarid portions of the Northwest, where demands for irrigation water continue to increase. Irrigation, through return flow, increases water temperature and reduces the dissolved oxygen content. In this connection, diversion dams can greatly increase the water surface area, and, thereby, contribute to an increase in water temperature. Outfalls from feed lots and fields along the stream tend to be low in dissolved oxygen, high in BOD, and high in water temperature.

Since temperature and oxygen changes will most likely result in biotic and chemical changes, it is essential to be able to estimate the changes in the thermal and oxygen regimes resulting from the introduction of water, which is warmer, higher in BOD, and lower in dissolved oxygen into the natural system. It would also be important to estimate temperature and oxygen changes due to changes in the flow regime and a combination of flow changes and advective changes. This can be attempted by using a dissolved oxygen-temperature model. Changes predicted by the model can be compared with tolerance limits of the affected organisms. In this way, the concentration and volume of additional heat, BOD, and low oxygen water, which can be introduced without detriment, can be estimated. The model used should predict temperature to $\pm$ 2° F and dissolved oxygen to $\pm$1 mg per liter.

Data Cost and Availability: Data cost and availability for the temperature portion of the model are small for the meteorological variables of air temperature, cloud cover, barometric pressure, relative humidity, and wind speed, since these are available from National Weather Service publications, although these are not near the water bodies in many cases. Discharges are available from USGS publications, and solar altitude can be obtained from tabled values or charts. Stream geometry can be obtained from elevational river profiles, travel times, and discharges. Elevational profiles and travel times can represent a considerable expense in terms of manpower. Collection of actual values of water temperature and dissolved oxygen and biomass to calibrate the model are probably the most expensive item.

Procedure: The stream must be divided into reaches. Flows must be estimated for each reach. Diversions and returns, in addition to natural inflows, must be estimated. BOD added, oxygen deficit added, temperature of incoming water, and travel time for each reach must be estimated. Surface area of the reach can be calculated. Meteorological variables required can be obtained from National Weather Service publications.

Required Data Inputs

A. Title card

B. Initial conditions card
   1. Water temperature - ^{o}F
   2. O_2 deficit - mg/l
   3. BOD - mg/l
   4. Flow - cfs
   5. Number of reaches +1
   6. Starting time
   7. Output switch
   8. Input switch

C. Reach
   Information for each reach (seven cards for each reach), K_1^{20}, K_2^{20}, BOD added, added deficit, temperature of incoming water (^{o}F), added flow, time to traverse reach (days), number of intervals

D. Next six cards
Net short-wave radiation (calculated from altitude of sun, percent cloud cover)
Atmospheric radiation factor β
Air temperature $^{\circ}F$
Wind speed (knots)
Ambient vapor pressure (inches Hg)
Surface area of plug (acres)

MODEL CALIBRATION

The model was calibrated to a data set collected on August 9, 1978, for three stream reaches. Travel time of the water was measured by using a float. Air temperature, relative humidity, water temperature, dissolved oxygen, BOD, percent cloud cover, stream width and depth, and wind speed were measured or estimated at 135008, 116083, and 106018 (Figure 5.a.5).

For each reach, net short-wave radiation from percent cloud cover and solar altitude was calculated. The atmospheric radiation factor was calculated from ambient vapor pressure and percent cloud cover. Air temperature and ambient vapor pressure were measured at each station, and wind speed was estimated for each reach. Average surface area of water was calculated from the width of the stream at each station and the length of the reach.

The model was first made to match the observed water temperatures at each station by varying the net short-wave radiation and wind speed inputs. Net short-wave radiation was decreased from the calculated values for each reach. This is because of shading of the water surface by vegetation and steep canyon walls, resulting in less short-wave input than that calculated from solar altitude and cloud cover. This is presently a serious defect of the temperature portion of the model, and will require the development of a shading factor to be applied to the calculated net short-wave radiation.

After satisfactory water temperature agreement was obtained, BOD calibration was attempted by varying K_d^{20}, the de-oxygenation coefficient, in small steps until satisfactory BOD agreement was obtained for each station.

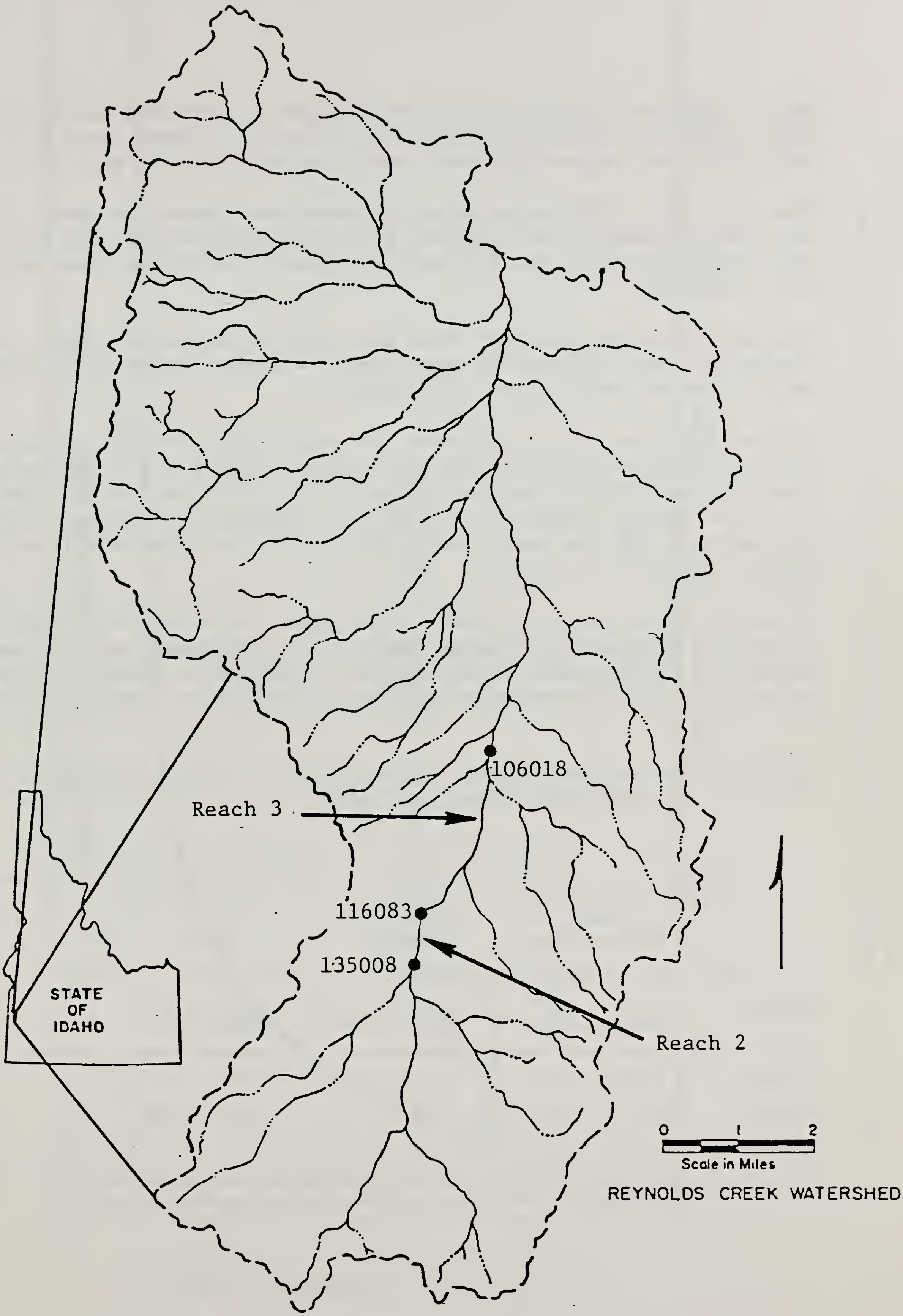

Figure 5.a.5--Stream reach and data sites for calibration of water quality model.

Next, dissolved oxygen content was matched to observed values by varying K_2^{20}, the re-oxygenation coefficient, in steps until satisfactory dissolved oxygen agreement was obtained for each station.

The results of this calibration procedure are listed in Table 5.a.2. Excellent agreement was obtained for all variables, but the values of the coefficients K_d^{20} and K_2^{20} are much lower than those reported in the literature.

This may be due to the fact that the reported values of these coefficients were developed on much larger streams having much greater surface areas, depths, and discharges.

Figures 5.a.6 and 5.a.7 indicate the sensitivity of K_2^{20} at the actual water temperature and BOD for each reach. Figure 5.a.6 indicates that for reach 2, K_2^{20} can vary from 0.25 to 4.40, and still simulate dissolved oxygen content to $\pm$ 1 mg/ℓ. Figure 5.a.7 indicates that for reach 3, K_2^{20} can vary from 0.20 to 2.00, and simulate dissolved oxygen content to $\pm$ 1 mg/ℓ.

It would appear, at the present time, that the model can produce an acceptable simulation of water temperature, dissolved oxygen, and BOD. Because of simple model construction, it should be possible to add other water-quality variables in the future with a minimum effort.

TABLE 5.a.2--Results of model calibration for water temperature, dissolved oxygen, and BOD.

	Water Temperature		Dissolved Oxygen		BOD		K_d^{20}	K_2^{20}
STATION	OBS.	SIM.	OBS.	SIM.	OBS.	SIM.		
135008	59.0	----	7.50	----	7.00	----	----	----
116083	64.4	64.4	7.25	7.27	7.25	6.99	0.004	1.80
106018	77.9	77.9	6.00	6.00	5.75	5.76	0.193	0.67

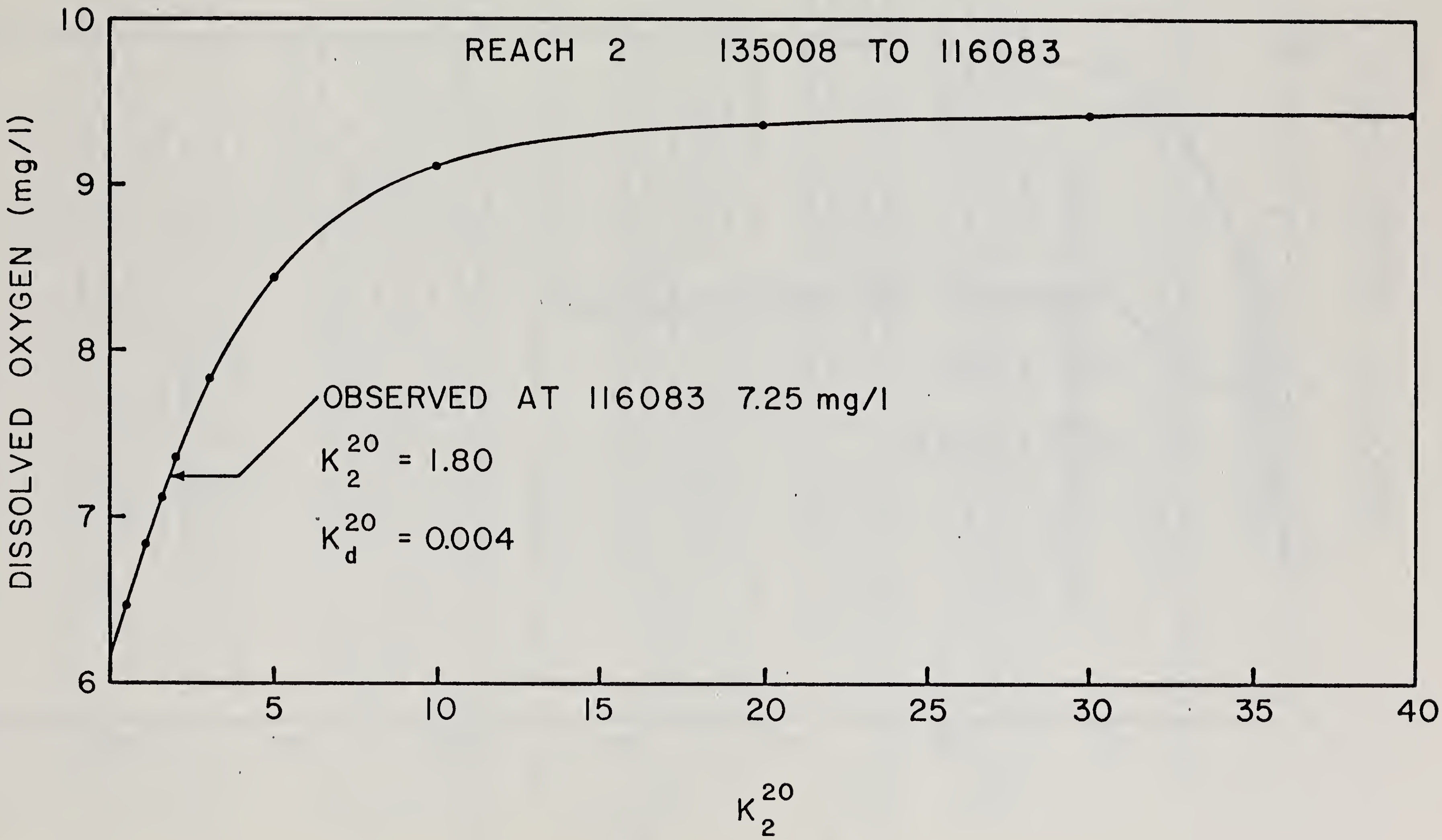

Figure 5.a.6--Variation of dissolved oxygen with re-oxygenation coefficient for reach 2.

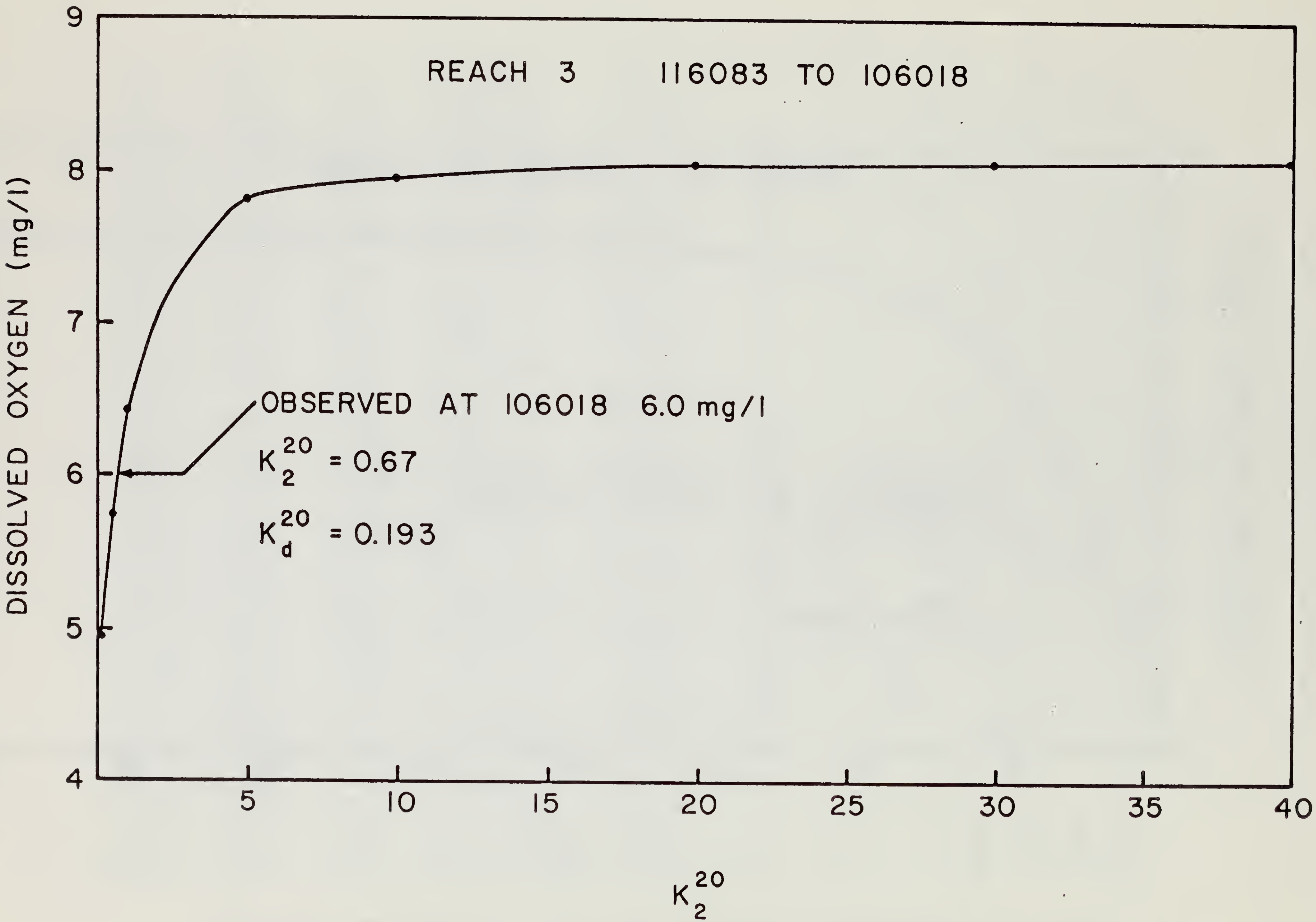

Figure 5.a.7.--Variation of dissolved oxygen with re-oxygenation coefficient for reach 3.

b. Boise Front Results

Map of Boise Front with location of water quality sampling sites is found on Figure 2, in the Introduction section.

BASELINE WATER QUALITY INFORMATION

Water quality information was developed from samples collected at four sampling sites on the Boise Front rest-rotation grazing system. The four sampling sites were chosen to correspond with the existing runoff-measuring sites, shown in Figure 2, in the Introduction.

The various water quality parameters for which samples were analyzed, and the results of these analyses, are given on Table 5.b.1. Only two samples were analyzed for chemical concentrations. The reason for the few number of chemical analyses is because of cost.

When comparing data from 1978 with that in the 1977 Annual Report, differences found, first, reflect the changes in grazing management, and second, differences in runoff characteristics. The former is reflected in generally increased bacterial concentrations for 1978, and the latter in decreased dissolved solids concentrations. Suspended solid concentrations were slightly higher in 1978

BACTERIAL INDICATORS FROM STREAMS IN DIFFERENT GRAZING SYSTEMS

During 1978, cattle were grazed in the Boise Front rest-rotation system in high pastures 1 and 2 and low pastures 1 and 2 only. High and low pastures in units 3 and 4 were rested this year from cattle grazing, but did incur grazing from sheep. Figure 5.b.1 shows the effect of the presence of cattle on bacterial indicators at the Upper and Lower Maynard sites in high and low pastures of unit 2. No sampling sites are located at this time in high and low pastures of unit 1, because of its inaccessibility.

Cattle were turned into low pasture 2 on May 18, and moved out to high pasture 2 by July 26. Fecal coliform concentrations at the Lower Maynard site in low pasture 2 increased immediately following the introduction of cattle, but dropped sharply within a month. The stream was dry at this site by July 10. Cattle grazed along the stream in low pasture 2 while water was available, but moved out to upland areas as streamflow diminished, making use of upland spring developments for

TABLE 5.b.1.--Water quality characteristics, Boise Front Watershed sampling sites.

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		UPPER MAYNARD WEIR (322W54)			
pH	units	18	8.30	7.30	7.77
Conductivity	μmhos	13	230.00	49.00	123.08
Dissolved solids	mg/l	13	158.70	33.81	84.93
Calcium	mg/l	2	23.45	18.24	20.84
Magnesium	mg/l	2	3.40	2.92	3.16
Sodium	mg/l	2	12.18	10.58	11.39
Phosphorous	mg/l	2	.05	.02	.04
Nitrate	mg/l	2	.06	.04	.05
SiO_2	mg/l	2	36.10	26.06	31.08
Sodium adsorption ratio	ratio	2	0.62	0.61	0.615
Suspended solids	mg/l	14	30.40	0.00	7.76
Total coliform	cts/100 ml	17	1580.00	40.00	433.88
Fecal coliform	cts/100 ml	17	780.00	0.00	217.35
Fecal strep	cts/100 ml	18	2005.00	10.00	319.00
COD	mg/l	14	9.90	5.10	7.28
BOD	mg/l	15	2.50	0.50	1.50
DO	mg/l	18	11.00	8.00	8.94
		HIGHLAND VALLEY WEIR (419W96)			
pH	units	19	8.40	7.41	7.77
Conductivity	μmhos	14	173.00	70.00	116.36
Dissolved solids	mg/l	14	119.37	48.30	80.29
Calcium	mg/l	2	17.43	16.63	17.03
Magnesium	mg/l	2	4.50	4.50	4.50
Sodium	mg/l	2	9.89	9.43	9.66
Phosphorous	mg/l	2	.27	.23	.25
Nitrate	mg/l	2	2.00	.62	1.31
SiO_2	mg/l	2	37.80	27.27	32.54
Sodium adsorption ratio	ratio	2	0.56	0.52	0.54
Suspended solids	mg/l	16	132.40	2.00	52.68
Total coliform	cts/100 ml	18	3770.00	0.00	648.06
Fecal coliform	cts/100 ml	18	2020.00	0.00	193.10
Fecal strep	cts/100 ml	19	4960.00	8.00	811.21
COD	mg/l	15	29.40	7.80	15.51
BOD	mg/l	16	3.00	1.00	1.94
DO	mg/l	19	10.50	7.50	8.76
		LOWER MAYNARD (328W57)			
pH	units	16	8.30	7.5	7.86
Conductivity	μmhos	11	190.00	62.00	124.64
Dissolved solids	mg/l	11	131.10	42.78	86.00
Calcium	mg/l	--	--	--	--
Magnesium	mg/l	--	--	--	--
Sodium	mg/l	--	--	--	--
Phosphorous	mg/l	--	--	--	--
Nitrate	mg/l	--	--	--	--
SiO_2	mg/l	--	--	--	--
Sodium adsorption ratio	ratio	--	--	--	--
Suspended solids	mg/l	12	41.20	2.00	12.49
Total coliform	cts/100 ml	16	2000.00	0.00	298.19
Fecal coliform	cts/100 ml	16	1720.00	0.00	225.56
Fecal strep	cts/100 ml	16	305.00	8.00	101.50
COD	mg/l	13	15.60	6.30	8.06
BOD	mg/l	14	2.00	0.00	1.32
DO	mg/l	16	10.50	7.00	8.75

TABLE 5.b.1.--continued

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		CAMP CREEK (336W12)			
pH	units	14	8.50	7.40	7.94
Conductivity	μmhos	9	190.00	90.00	130.78
Dissolved solids	mg/l	9	131.10	62.10	90.24
Calcium	mg/l	--	--	--	--
Magnesium	mg/l	--	--	--	--
Sodium	mg/l	--	--	--	--
Phosphorous	mg/l	--	--	--	--
Nitrate	mg/l	--	--	--	--
SiO_2	mg/l	--	--	--	--
Sodium adsorption ratio	ratio	--	--	--	--
Suspended solids	mg/l	--	--	--	--
Total coliform	cts/100 ml	14	472.00	0.00	165.57
Fecal coliform	cts/100 ml	14	280.00	0.00	38.57
Fecal strep	cts/100 ml	14	345.00	4.00	80.21
COD	mg/l	6	9.20	3.70	6.88
BOD	mg/l	--	--	--	--
DO	mg/l	14	10.50	7.50	8.81

drinking water. The diminishing fecal coliform concentration for the Lower Maynard site on Figure 5.b.1 reflects this change in cattle activity in late June and early July.

Sheep passed through high pasture 2 early in May. Their presence is reflected in the increased fecal coliform concentrations for the Upper Maynard site on Figure 5.b.1. Following removal of sheep from high pasture 2 on May 30, fecal coliform concentrations remained at an elevated level at the Upper Maynard site until early July. The reason for this may be that cattle from low pasture 2 were able to get into the stream segment at the Upper Maynard site as water was still flowing in this segment of the stream. The Upper Maynard site is located just below the boundary fence; and, if the stream below the site was dry, cattle could seek out the site for drinking water. No positive observations of the cattle at the site were made, but the biweekly visits were possibly not frequent enough.

Figure 5.b.1 shows a sudden increase in fecal coliform concentrations for the Camp Creek and Highland Valley sites in late May. This is the result of sheep moving through these fields, even though the pastures were in the rest period for the rest-rotation grazing system.

When comparing bacterial indicators from streams in the grazed and ungrazed portions of the rest-rotation system, concentrations from sites in the grazed system are several orders of magnitude higher than in the ungrazed. The elevated levels of fecal coliform concentrations in the ungrazed fields are the result of the sheep passing through, and would undoubtedly follow the previous low levels for the early part of the year, if the band of sheep had not been present. Several bands of sheep were kept in high pasture 3 for the month of November 1977, resulting in very high fecal coliform concentration at the Highland Valley site at the time (Figure 5.b.1).

A comparison of the effect cattle grazing has on bacterial indicators of streams under different management systems can be seen by referring to Figure 5.b.2. The deferred management system on the Reynolds Creek Watershed is represented by sites in the Soldier Cap and Salmon Butte fields, and the rest-rotation system on the Boise Front by sites in high and low pastures of unit 2. The fecal coliform concentration curves on Figure 5.b.2 are similar for the grazed fields in both systems.

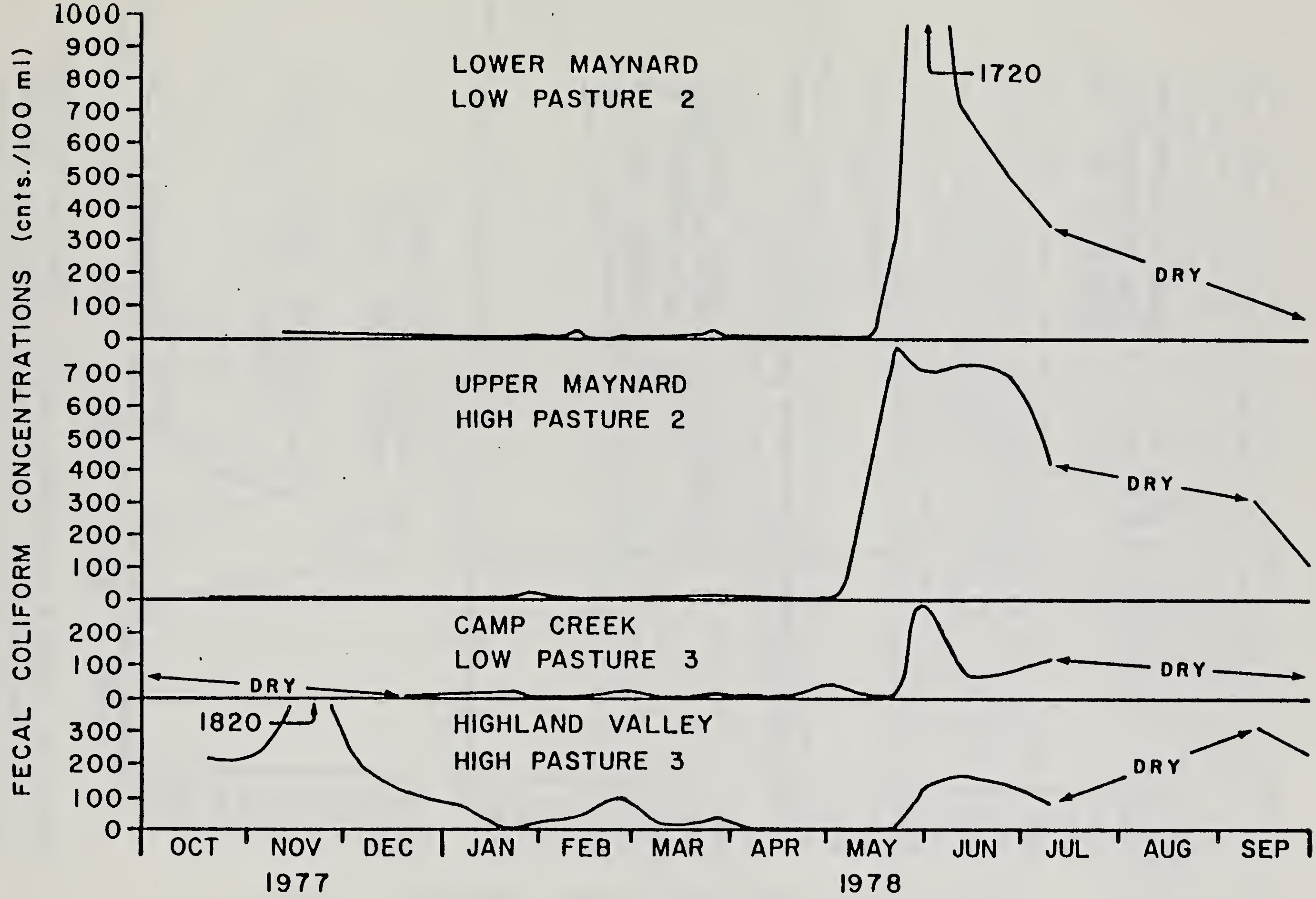

Figure 5.b.1.--Fecal coliform concentration--Boise Front sampling sites.

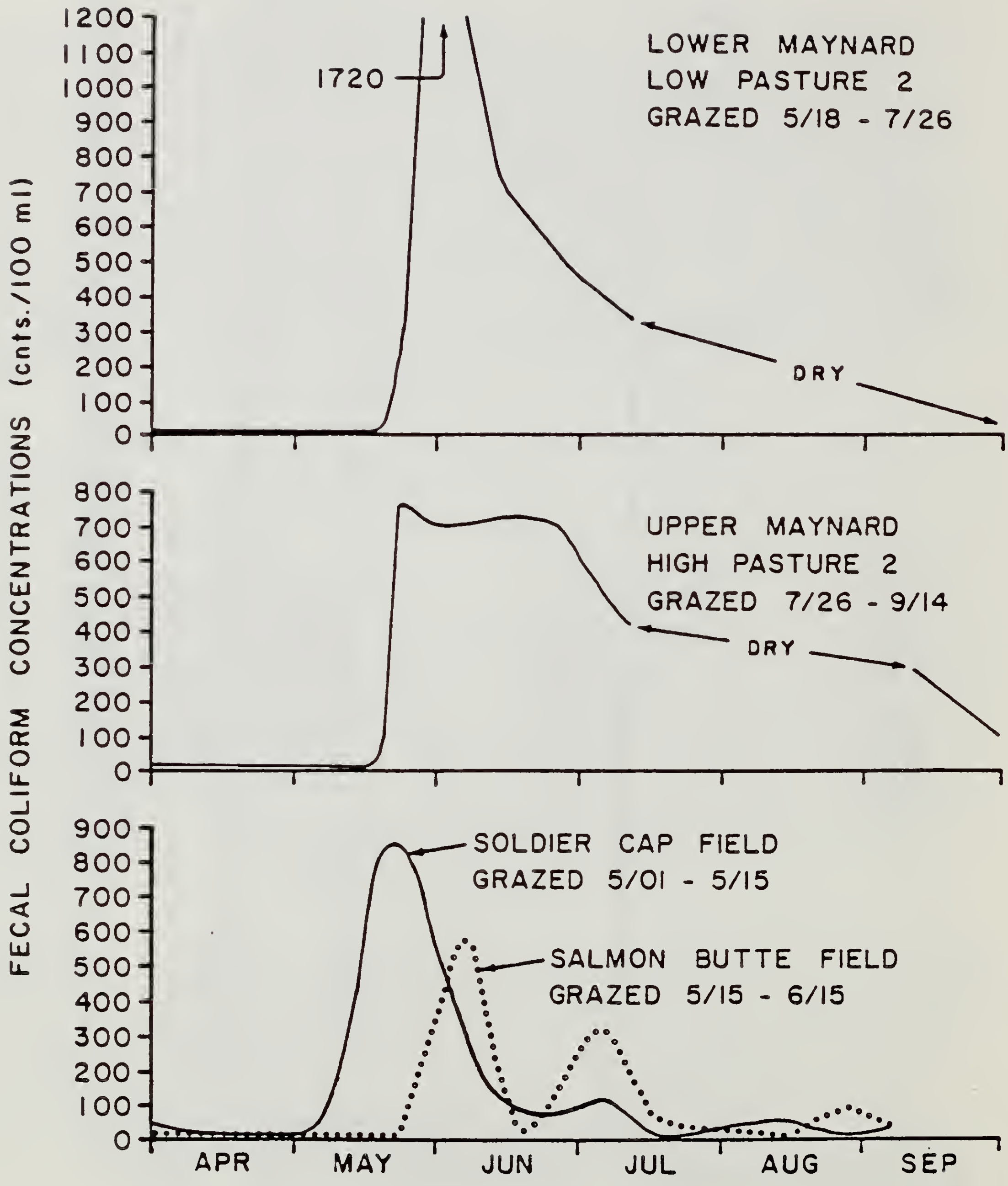

Figure 5.b.2.--Effect of grazing on stream quality under two different grazing systems, Lower and Upper Maynard sites located in Boise Front rest-rotation system. Soldier Cap and Salmon Butte fields located in deferred rotation fields on Reynolds Creek Watershed. Approximately 1000 head grazed in deferred fields and 204 head of cattle and 1000 head of sheep in the rest-rotation fields.

Under both systems, the fecal coliform concentrations increase rapidly soon after cattle are turned into the fields. Cattle are grazed for a longer period of time in the rest-rotation fields than in the deferred rotation fields. The fecal coliform concentrations from the rest-rotation fields decrease more slowly than for the deferred rotation sites, which is the result of length of time the cattle graze in the respective units.

The higher peak concentration for the Lower Maynard site (low pasture 2) reflects, mainly, the concentrations of cattle along the stream when they are first turned in. However, the decrease in the concentration curve following its initial peak reflects the use of the upland springs by the cattle as they move away from the stream to graze. The stream is the main source of stock water in high pasture 2, above the Upper Maynard site.

From December through April, a large herd of deer winter through the Boise Front grazing area. Figure 5.b.1 shows that a low level of fecal coliform counts were recorded at all sites during this time, which probably reflects the heavy deer population. However, the highest fecal coliform concentration recorded from a single water sample was only 100 cnts/100 ml on February 27 at the Highland Valley site. The bacterial indicator data so far do not suggest a serious stream pollution problem related to the presence of deer.

PROGRESS REPORTS (ACHIEVEMENTS)

1. PRECIPITATION

Hanson, C. L., R. P. Morris, and D. L. Coon. A note on the dual-gage and Wyoming shield precipitation measurement systems. (Accepted for publication in Water Resour. Res.).

Hanson, C. L., R. P. Morris, R. L. Engleman, and C. W. Johnson. Spatial and temporal precipitation distribution on Reynolds Creek Experimental Watershed in southwest Idaho. (Approved for publication in AR Series, Western Region, 1979).

2. VEGETATION

Hanson, C. L., J. F. Power, and C. J. Erickson. 1978. Forage yield and fertilizer recovery by three irrigated perennial grasses. Agronomy J. 70(3):373-375.

Schumaker, G. A., C. L. Hanson, and C. W. Johnson. Loss of mountain big sagebrush (*Artemisia tridentata vaseyana*) stands in southwestern Idaho during the winter of 1976-77. (Accepted for presentation at the Soc. for Range Manage. Ann. Meeting in February 1979).

3. RUNOFF

Brakensiek, D. L. Discussion on 'Empirical equations for some soil hydraulic properties' by R. B. Clapp and G. M. Hornberger. Water Resour. Res., Vol. 14, No. 4, (Accepted for publication in Water Resour. Res.).

Brakensiek, D. L. Empirical and simplified models of the infiltration process. (Accepted for publication in Proc. of USDA-AR Infiltration Research Workshop, NCR Publication).

Brakensiek, D. L., W. J. Rawls, and W. R. Hamon. 1978. Application of an infiltrometer system for describing infiltration into soils. (Accepted for publication in Trans. of ASAE).

Burgess, M. D. and C. L. Hanson. Automatic soil-frost measuring system. (Accepted for publication in Agr. Meteorol.).

Hanson, C. L. 1978. Frost-measuring network predicts winter flooding. Soil Conserv. 44(5):22.

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Hanson, C. L., A. R. Kuhlman, and J. K. Lewis. 1978. Effect of grazing intensity and range condition on hydrology of western South Dakota ranges. South Dakota Agr. Exp. Sta. Bull. 647. 54 p.

Hanson, C. L.and D. A. Woolhiser. 1978. Probable effect of summer weather modification on runoff. J. Irri. and Drainage Div., ASCE, 104(IRI):1-11.

Hanson, C. L. and J. K. Lewis. 1978. Winter runoff and soil water storage as affected by range condition. First International Rangeland Congress, Soc. for Range Manage., Denver, CO, Aug. 14-18, 1978. p. 28. Abstract.

Hanson, C. L. and J. K. Lewis. 1978. Winter runoff and soil water storage as affected by range condition. Proc. of the First International Rangeland Congress, Soc. for Range Manage., Denver, CO, Aug. 14-18, 1978.

G. R. Stephenson and J. F. Zuzel. 1978. Groundwater recharge characteristics in a semiarid environment. Prepared for Memorial Volume, J. of Hydrol.

Woolhiser, D. A. and D. L. Brakensiek. Hydrologic systems syntheses. Presented at 1978 Winter Meeting, ASAE. (Accepted for publication in an ASAE monograph on watershed modeling).

4. EROSION AND SEDIMENT

Johnson, C. W., G. A. Schumaker, and J. P. Smith. Effects of grazing and brush control on sagebrush rangeland erosion by the Universal Soil Loss Equation. (Accepted for presentation at the Soc. for Range Manage. Ann. Meeting in February 1979).

Johnson, C. W. and J. P. Smith. 1978. Sediment characteristics and transport from northwest rangeland watersheds. Trans. of ASAE. 21(6):1157-1162; 1168.

Johnson, C. W. and J. P. Smith. 1978. Reducing stream sediment loads by irrigation diversions. Paper No. 78-2088 presented at the Summer Meeting, ASAE, Logan, UT, June. (Accepted for publication in Trans. of ASAE, October 1978).

5. WATER QUALITY

G. R. Stephenson. Effect of drought condition on groundwater supplies in a rangeland watershed in southwest Idaho. (Accepted for presentation at AGU Ann. Meeting., Wash., D. C., May 1979).

G. R. Stephenson and J. E. Dixon. Evaluation of rangeland management practices for improved water quality. (Prepared for presentation at 1979 ASAE Winter Meeting, New Orleans, LA).

APPENDIX

APPENDIX I

PROGRESS SUMMARIES

1. PRECIPITATION

The Wyoming shield precipitation gage caught very nearly the same precipitation totals as the dual-gage system. It has the advantage of requiring only one gage at a measurement site. Also, it appears to provide a much smoother ink trace on the recorder chart, even under extremely windy conditions.

A stochastic model for monthly and annual precipitation amounts has been tested with Reynolds Creek network data. Aspect and elevation are included as variables for predicting the mean and variance in the simulation equations.

2. VEGETATION

Preliminary analyses indicate that the annual herbage yield is related to effective precipitation at a specific location. At locations that are below about 5500 feet, the sum of the precipitation for the months of November through one month before harvest relates best with herbage yield. At locations above about 5500 feet, two separate precipitation seasons have to be taken into account. The first period is the snow accumulation season, and the second period is the spring rain and snow.

3. RUNOFF

As part of a SEA cooperative study on rangeland runoff, SCS curve numbers were developed for the Northern Great Plains. These were verified with SEA-AR watershed data.

Parameter values for the Green and Ampt infiltration equation can now be estimated from soil moisture characteristic data (desorption data). Application of the infiltration equation for runoff prediction from a Reynolds Creek Watershed is illustrated.

Correlation of annual runoff amounts with precipitation amounts and/or indices shows that accurate runoff predictions can be made. Correlations between monthly precipitation-runoff amounts were much less, indicating additional factors, not necessarily as a linear relationship, are required. Correlations between monthly Boise Front Watershed runoff and Reynolds Creek Watershed runoff indicate a close relationship. This relationship will be useful for estimating Boise Front monthly runoff and evaluating runoff changes.

4. EROSION AND SEDIMENT

An analyses of irrigation diversions in the Reynolds Creek Watershed indicate that about 17 percent of the sediment contained in diverted water is deposited in the irrigated area.

The Universal Soil Loss Equation (USLE) is used to compare the potential soil loss from grazed and nongrazed sites. Alternative brush control measures are also compared.

5. WATER QUALITY

A baseline value of 30 fecal coliform concentration/100 ml has been established, separating open range streamflow sites from pasture sites (wintering fields). Downstream reductions of fecal coliform concentrations from upstream sites have been quantified.

The reduction of streamflow fecal coliform concentrations resulting from upland spring development has been observed. Development of these upland water sources have been assumed to be a management practice that reduces streamflow pollution because it may reduce cattle in stream and stream bank concentrations. It can now be recommended as a proven nonpoint pollution control practice.

Progress is reported on the calibration of a water quality model applicable to rangeland streams. Water temperature, BOD, and dissolved oxygen content are the principle model outputs.

With the collection of baseline data on the Boise Front Rest-Rotation Watersheds, comparisons can now be made with the deferred system on Reynolds Creek. Under both systems, fecal coliform concentrations increase rapidly after cattle are introduced. Concentrations remain higher and for a longer period of time for the rest-rotation, as cattle remain in rest-rotation fields longer than in the deferred pastures.

APPENDIX II

ANNUAL WORK PLAN FOR FY 1979

INTRODUCTION: The following activities are necessary to meet the objectives stated in Paragraph III of Bureau of Land Management Interagency Agreement No. YA-515-IA8-21 dated September 19, 1978. Certain elements in this plan of work indicate continuation of work from previous years. In many cases, this continuation of inventory is required to sample climatic variability and to evaluate the cumulative effects of grazing practices on hydrologic processes and watershed, soil, water, and vegetal factors. SEA research on Reynolds Creek and the Boise Front will supplement many of the items contained in this work plan.

1. PRECIPITATION

Develop and display via maps or tabulations, (12 sets) modeling of Reynolds Creek Watershed monthly and annual precipitation amounts. Initiate preparation of similar material for comparable areas of Idaho, Oregon, and Nevada. Commence development of a daily amounts stochastic precipitation model from Reynolds Creek data. A summary of Reynolds precipitation data will be reported in an SEA publication. Precipitation network operation will be continued on Reynolds and at satellite watersheds.

2. VEGETATION

Complete and report on development and application of a climate-forage yield model, to include sensitivity analyses and model verification. Continue annual vegetative surveys on the Boise Front, which will consist of species composition, cover seedling density and kind, and establishment. Determine late cover at eight SEA vegetation sites at Reynolds Creek. Data are to be reported in the 1979 FY Annual Report.

3. RUNOFF

Perform a probability analyses of Reynolds Creek Watershed runoff amounts at six runoff stations. Continue evaluation of the SCS runoff equation for watersheds at Reynolds Creek and at two runoff stations on the Boise Front rest-rotation system.

4. EROSION AND SEDIMENT

Determine USLE soil loss and PSIAC sediment yields for selected range sites on Reynolds Creek. Report cover and soil loss values in FY 1979 annual report. Continue sediment sampling at four sites on Reynolds Creek and two sites on the Boise Front.

5. WATER QUALITY

Complete report on the calibration of a water quality model (DO, BOD, Total Biomass) for Reynolds Creek. Complete a SEA report on water quality data for Reynolds Creek. Continue water quality sampling on the Boise Front rest-rotation system.

6. RAINFALL SIMULATION

The experimental design will be formulated and field sites selected for FY 1980 field tests. The soil, vegetal, and other plot descriptors to be used during FY 1980 will be selected, and measurement procedures developed for their use. Physical requirements and logistics and planning actual rainfall simulator test procedures will be evaluated and developed.